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ABSTRACT

This guide to assessing engineering education in Sub-Saharan Africa consists of three sections, covering: (1) assessment of qualitative and quantitative needs; (2) assessment of the engineering education institution in developing countries; and (3) methods of forecasting demand for engineers; assessment of the efficiency of engineering training institutions; questionnaires concerning students, staff, curriculum, examinations, research, buildings and equipment, libraries, and other topics in assessing engineering education institutions from a systems point of view; and methodologies for analyzing costs. The guide contains papers with the following titles and authors: "Different Methods of Assessment" (Malcolm Frazer); "Quality in Engineering Education" (John Sparkes); "Reviewing Quality" (Ton I. Vroeijenstijn); "Guidance for an Evaluation Committee" (T. P. Melia); "Internal Evaluation Methods" (John Dubbey); "Engineering Education for the Labor Market in Africa" (K. Koso-Thomas); "Methodology for Designing Engineering Curricula in a Developing Country" (Benjamin A. Ntim); and "Assessing Engineering Schools" (Manuel Zymelman). Appendixes contain questionnaires, cost formulas, and average and high values of occupational composition of industries. (References accompany each paper.) (JDD)

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WORLD BANK TECHNICAL PAPER NUMBER 197
AFRICA TECHNICAL DEPARTMENT SERIES

Assessing Engineering Education in Sub-Saharan Africa

Manuel Zymelman, editor

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Assessing Engineering Education in Sub-Saharan Africa

Manuel Zymelman, editor

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Abstract

The future of Sub-Saharan Africa will depend to a large extent on the abilities of the Sub-Saharan societies to introduce technological change as a permanent ongoing process. Engineering capacity will be a major factor in fostering this ability. Thus, the development of engineering education should command the attention of human resources and education planners. The goal of a development plan for engineering education is to ensure that the required number of engineers of a specific standard are produced in an efficient manner. In the case of Sub-Saharan Africa, it is necessary to transform the present engineering education system into a new system that satisfies this development goal. But in order to do that it is first necessary to assess the present system.

Assessment of educational systems in general, and of engineering education in particular, is an old and venerable practice in industrialized countries. This volume explores the different meanings of assessment and the possibility of using known assessment methods in Sub-Saharan African context.

To help the practitioners in their tasks, this book provides a practical guide to assess an engineering education institution. This guide approaches assessment in a comprehensive manner. It has three main sections. The first two deal with the assessment of qualitative and quantitative needs, and assessment of the efficiency of the engineering education institution. The third section contains questionnaires, and methodologies for analyzing costs. As with any guide, the type of questions and data requirements have to be adapted to the specific task at hand and to local conditions.

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Foreword

Economic development of Sub-Saharan Africa depends to a large extent on the ability of African societies to introduce and maintain technical change. This ability requires the capacity to choose, acquire, adapt, generate, and apply technologies. Engineering education is one of the most important vehicles for developing this capacity.

Engineering education in Sub-Saharan Africa is deteriorating rapidly, both quantitatively and qualitatively, as a result of budget constraints. The deterioration of quality is worrisome. Without a steady increase in quality to enable engineers and technicians to keep up with international technological advances, the countries of Sub-Saharan Africa will fall further and further behind their competitors.

To stem this deterioration in quality and expand the system to confront the economic needs of the sub-continent, the existing systems of engineering education should be transformed. To map out the steps required to effect this transformation, we must first assess the existing system.

This volume presents a series of papers dealing with the assessment of engineering education institutions in Sub-Saharan Africa in particular. The last part of the compendium includes a practical guide and a checklist for assessors of engineering education.

This publication is intended for the staff of development agencies, government officials, and academicians concerned with assessment and planning of engineering education.

We hope that the concepts and methodologies presented here will contribute to a better understanding of the issues in engineering education and that they will provide a framework for future assessments of engineering education institutions in Sub-Saharan Africa.

Ismail Serageldin
Director
Technical Department
Africa Region

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Manuel Zymelman

Executive Summary

Economic development in the countries of Sub-Saharan Africa depends critically on the ability of their societies to establish technological progress as an ongoing process. Engineering education is a basic ingredient in this process.

Engineering education in Sub-Saharan Africa is in a sorry state. Developed countries graduate 166 times more engineers per capita than do the countries of Sub-Saharan Africa, and the quality of training, already low, is deteriorating as a result of budget constraints. This deterioration of quality is most worrisome. For without a steady increase in quality to enable engineers and technicians to keep up with international technological advances, the countries of Sub-Saharan Africa will fall further and further behind.

How can we stem the decline in quality? How can we ensure that quality of engineering education in Sub-Saharan Africa attains international standards and continues to improve? How can we ensure that the required number of engineers of a specific standard are produced in an efficient manner?

The answer to these questions requires a series of steps to transform the present engineering education system into a new system that has the attributes of good quality and functional efficiency. But to map out these steps it is necessary first to define the present system and its characteristics, that is, we must assess the present system.

Assessment of education systems is an old and honored endeavor practiced by institutions, associations, and governments. Historically, however, most of the theory and practice of assessment dealt with industrialized countries. Should the countries of Sub-Saharan Africa, in a quest to improve their engineering institutions, replicate the assessment methods followed in developed countries? To answer this question, two meetings were held in 1991. A meeting of European experts was held in Brussels, and another of African experts was held in Harare. A compendium of selected papers presented at the meetings is included in this volume.

This volume consists of three parts. The first group of papers is concerned with concepts of assessment. "Different Methods of Assessment", by Dr. Malcolm Frazer, deals with the questions of *why* do we need quality assurance, *what* qualities should be assured, and *how* should quality assurance be undertaken, and offers recommendations on ways to find answers to these questions. "Quality in Engineering Education", by Professor John Sparkes, makes the point that before any assessment can be made it is necessary to consider how a worthwhile set of educational goals can be arrived at. It presents a matrix of different types of learning, by type of resources required, by the educational process they entail, and by the assessment methods that are appropriate for each type of learning.

The paper "Reviewing Quality", by Dr. Ton I. Vroeijenstijn, discusses the concept of quality with reference to two questions: can quality be quantified, and can standards be set for quality? Drawing from his experience in Dutch universities, Dr. Vroeijenstijn proposes a system of quality control and its validity for assessing engineering education in developing countries.

"Evaluation of Engineering Education in a Third World Country: Guidance for an Evaluation Committee Visiting an Engineering College", by Dr. T.P. Melia, provides a summary description of the assessment work done by Her Majesty's Inspectorate in Great Britain with special reference to the inspection of Higher Education in Engineering from whence it derives practical recommendations for an evaluation committee visiting an engineering college.

Based on his experience as Dean of Engineering at a London polytechnic and Vice Chancellor of the University of Malawi, Professor John Dubbey in "Internal Evaluation Methods" discusses internal evaluation with respect to the academic community itself, the educational institution concerned, and the world of industry and commerce.

The second group of papers deals more specifically with assessment of engineering in developing countries. "Engineering Education for the Labor Market in Africa", by Professor K. Koso-Thomas, raises the question of what kind of engineer and, hence, what type of engineering education is needed in Africa. Should engineers be trained only for current needs? How adaptable should engineers be? How attuned to the environment? On the basis of this discussion, Professor Thomas suggests undergraduate and graduate course patterns for African countries.

The second paper of this group, "Methodology for Designing Engineering Curricula in a Developing Country", by Dr. Benjamin A. Ntim, presents a systematic methodology for designing an engineering curriculum in developing countries, which serves at the same time as a framework for assessment of engineering institutions.

The third part of this compendium is a practical guide for assessors. "Assessing Engineering Schools", by Dr. Manuel Zymelman, approaches assessment of an engineering education institution from a systems point of view, and is meant to be a systematic checklist for those assessing engineering education institutions. But as with any guide, the type of questions and the data requirements have to be adapted to the specific task at hand and to local conditions.

This guide has three main sections. The first two are Assessment of Qualitative and Quantitative Needs, and Assessing the Efficiency of Engineering Training Institutions. The third section contains questionnaires for use by the assessors. The appendix and data forms provide data and methodologies for analyzing costs.

Contributors

Prof. John M. Dubbey is Principal of Botswana Polytechnic. Previously he was Vice Chancellor of the University of Malawi. Before going to Africa he worked at Thames Polytechnic and South Bank Polytechnic in London successively Head of Mathematics and Dean of Engineering.

Dr. M.J. Frazer CBE is the Director and Chief Executive of the Council for National Academic Awards in the United Kingdom. He taught at the Polytechnic of North London and was Professor, Dean, and Pro-Vice Chancellor at the University of East Anglia.

Dr. Terry Melia is the head of Her Majesty's Inspectorate of Schools in England. He formerly headed the higher education arm of Her Majesty's Inspectorate and developed the methods used to inspect higher education in the polytechnics and colleges which have been adopted for the inspection of English universities.

Dr. Benjamin Ntim obtained his Ph.D. in aeronautical engineering from Queen Mary College, London University, and lectured in mechanical engineering at the University of Science and Technology, Kumasi, Ghana. He is at present responsible for the planning and execution of Unesco's program in engineering and technician education.

Prof. John J. Sparkes taught at Imperial College and Essex University before joining the Open University where he served as Pro-Vice Chancellor and Dean of Technology. He has published books and papers on electronics and has written on engineering education and how it might be improved.

Prof. K.Koso-Thomas is Vice Chancellor of the University of Sierra Leone where he was previously Professor and Dean of Engineering. He has written extensively on engineering education in Africa.

Dr. Ton Vroeijenstijn is senior policy advisor to the Association of Universities in the Netherlands with particular reference to external quality assessment and was recently project leader of the International Program Review of Electrical Engineering. Previously he was engaged in the support and coordination of the Centers for Research and Development in Higher Education at Dutch universities.

Dr. Manuel Zymelman is senior advisor in the Division of Education of its Africa Technical Department at the World Bank. He taught at Northeastern and Harvard Universities and the Fletcher School of Law and Diplomacy. He is the author of books and articles on manpower, training, and educational finance.

Part I

Concepts of Assessment

Malcolm Frazer

Different Methods of Assessment

This topic has been chosen on the assumption that "different assessment methodologies" refers to the evaluation of courses, departments and institutions, and not solely to the assessment of students. Evaluation methods should be the same in developing countries as in developed countries, so this discussion does not include many specific references to the former.

A concern, not only to maintain but also to enhance quality in higher education, is now strongly articulated in many countries. This is particularly so for vocational disciplines, such as engineering, which are crucial to economic growth and the quality of life.

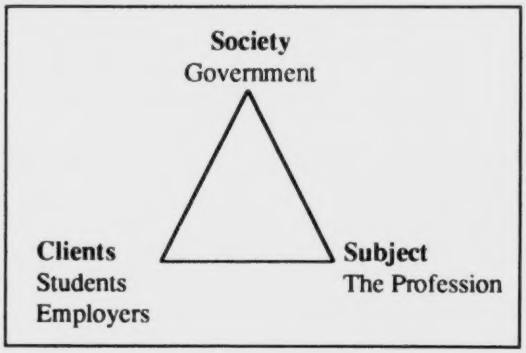
The process of maintaining quality to agreed standards and striving to improve quality beyond those standards can be described as quality assurance. Why do we need quality assurance? What qualities should be assured? How should quality assurance be undertaken?

This discussion is concerned mainly with the third question—the methods of quality assurance—but because the three questions are interrelated, there has to be mention first of "why" and "what".

Why?

Sometimes the question "why do we need quality assurance in higher education?" is answered by the word "accountability". That answer immediately provokes a second question "accountable to whom?". The answer to this question is complex because higher education, comprising teachers, course teams, departments, faculties, and institutions, is accountable to at least three different groups, shown in the triangle in Box 1.1.

Box 1.1: Accountability to Higher Education



Society wants value for money, efficiency, from its investment in engineering education. Government and associated funding agencies act for society in determining how much to spend on the education and training of engineers and whether the money is well spent.

Some departments are of higher standard than others. How should the available funds be allocated?

Should higher levels of funding go to departments with high standards as a reward or "carrot" to encourage all departments to strive towards these standards, or to departments with lower standards in order to raise them, at least to an acceptable threshold standard?

Conversely, should lower levels of funding go to departments with high standards (the quality might fall but will still be above the threshold), or to departments with low standards as a punishment or "stick"?

The clients of higher education are the students and the employers of graduates. They desire to have the best possible education available and need certification, in the form of degrees and diplomas, that particular levels of knowledge and competence have been achieved.

The third corner of the triangle is the subject of engineering itself. The knowledge, skills and attitudes which comprise engineering must not be distorted, suppressed or misused. Teachers of engineering are accountable to their profession that the essential truths are upheld and that students develop a strong professional ethos.

The various agencies concerned with quality in higher education can be positioned within the triangle according to their prime purpose.

Any understanding or analysis of methods of assessment of quality must depend first on clarity of purpose. Is the assessment aimed at making financial or planning decisions? Is the assessment aimed at accrediting courses, departments or institutions, perhaps legally empowering degrees or diplomas to be awarded or perhaps giving professional recognition? Is the assessment aimed at making improvements in standards? In summary, the purposes of evaluation may be related to financing and planning, certifying, or improving.

What?

Linked to the question of purpose is the question of what is to be assured. Is it an individual teacher? Is it a group of teachers comprising a course team? Is it a whole department? Is it a group of departments comprising a school or faculty? Is it the whole institution? We may wish to evaluate the quality of one or more of these, but at the heart of quality assurance in higher education is the evaluation of student learning.

This is summarized in Box 1.2. For each of the six subjects for evaluation, (column 1), there will be characteristics to describe high quality, (column 2). Columns 3, 4 and 5 refer to evaluation. The choice of method(s) of evaluation, (column 5), will depend in part on the criteria for the characteristics of quality, (column 3), and the purposes of the evaluation (column 4).

Box 1.2: Evaluation in Higher Education

1 Subject	2 Characteristics of Quality	EVALUATION		
		3 Criteria for each characteristic	4 Purpose	5 Method
Teacher	Box 1.3		Box 1.5	
Course-Team				
Department				
Faculty				
Institution				
LEARNING	Box 1.4			

There are twenty four cells in the table, each of which could be the subject of a paper on its own. This discussion is largely about column 5, but three cells will first be briefly developed. These are characteristics of quality teachers, characteristics of quality learning, and the purposes of evaluating teachers.

The characteristics of a quality engineering teacher in higher education are listed in Box 1.3, the characteristics of successful, quality learning in engineering described in Box 1.4, and the purposes of evaluation of a teacher in Box 1.5.

Box 1.3: Characteristics of a High Quality Teacher

- Up-to-date professional knowledge, skills and competence in engineering is the *sine qua non* for every teacher. Engineering competence can only come through direct practical experience of solving real problems. In developing countries there is no shortage of such problems.
- Affective characteristics such as love of engineering, a desire to share that love with others, a willingness to go on learning, a desire to help others learn and develop, and a willingness to self-evaluate performance as a teacher and to seek feedback from students and criticism from others, and finally a willingness to work in a team.
- An understanding of how people learn, and of any special learning difficulties associated with specific knowledge and skills to be taught and with the particular students, a realization that the most important task in promoting learning is to motivate the students.
- Personal characteristics such as a sense of humor, patience, confidence, capacity for hard work.
- Competence with teaching techniques including audio-visual and other methods, competence with assessment methods.

Box 1.4: Characteristics of High Quality Learning

- Love and respect for engineering and a desire to see engineering contribute to solving problems in developing countries.
- Professional competence in engineering.
- Knowing how to learn more about engineering and to develop new skills.
- Realization that learning is a life long process.
- Problem solving or opportunity taking, (i.e., problem recognition, definition and formulation of solutions, or approaches to solutions).
- Communication skills (writing and reading; speaking and listening).
- Critical analysis.
- Knowing how to find out (i.e., how to use libraries and other data-bases).
- Working in a team.

Box 1.5: Purpose of Evaluation

Evaluation of a teacher might be for one of three purposes:

- Financing and Planning - appraisal for determination of salary.
- Certifying - for example, confirming an appointment after a probationary period or conferring a title such as professor or docent.
- Improving - this is the most important purpose and is an opportunity to identify strengths and weaknesses, and to identify staff development needs.

How? - Methods of Evaluation

The essential feature of quality assurance in higher education is self-evaluation. Inspection and quality control imposed solely from outside would not be suitable to achieve the purposes outlined earlier. Self-evaluation—seeing oneself—is never easy but without two aids it is virtually impossible. The first aid is a "mirror", that is external assistance with self-evaluation. The work of quality assurance agencies, such as accrediting and validating bodies, audit units, and inspectors, is largely to help those engaged in higher education, whether it be an individual teacher or a whole institution, to see themselves more clearly. The second aid is training for the task of self-evaluation. Both these aids have a cost. However, expenditure on them should not be seen as an optional luxury but as a high priority if the quality of engineering education in developing countries is to be improved.

Recommendation 1

National and international quality assurance agencies should be used to assist engineering faculties in developing countries with self-evaluation.

Recommendation 2

Staff development programs on methods of quality assurance should be established, perhaps on a cooperative international basis.

Quality assurance agencies should provide external help for self-evaluation by three means.

First, self-evaluation should be assisted by peer experts in the field. Peer review is a major ingredient of quality assurance.

Second, quality assurance agencies should act a mediators by bringing together the clients (students and employers) and the institution. Formative and summative student feedback and views of employers of graduates should be a major contribution to maintaining and enhancing quality. Unfortunately, in many countries it is not part of the culture to seek the views of students. Part of the staff development programs must be directed towards changing this attitude and to demonstrating that it is a strength, not a weakness, to seek views of students, and that student feedback is valuable in improving courses and teaching. Students also need training on how best they can contribute to the quality assurance processes.

Information, such as current and best practice in teaching and learning in specific subject areas, qualitative and quantitative performance indicators, must be provided for the external peers and for the internal evaluators. This can be done via workshops, conferences, publications, access to data-bases, and so forth.

Recommendation 3

International agencies, (probably one Anglophone and one Francophone), should be established to provide information to assist with evaluation aimed at improving engineering education in developing countries in Africa.

Quality assurance should be comprehensive and examine inputs, processes and outputs.

Inputs include factors relating to the students (qualifications, experience and aspirations), factors relating to the teaching staff (professional experience, qualifications, staff development on teaching), factors relating to the secretarial and technical staff, and factors relating to the physical facilities (workshops, laboratories, classrooms, and in particular the library).

Another important aspect to be considered under the heading of inputs is the intention of the courses. For every course, the team of teachers should have prepared a document setting out the context of the course, its aims and objectives, its structure, its content and teaching methods and methods of assessment. Such a document should be widely available, should be based on a self-critical planning process involving consultation with peers and clients.

Recommendation 4

For every engineering course in higher education in developing countries a course document should be prepared and made public. It should contain a statement of the context, aims and objectives, structure, content and methods of teaching and assessment.

Processes. Self-evaluation must be concerned with the processes of teaching and learning. An effective course team will be constantly monitoring how the course is proceeding, the difficulties and successes of the students and logistical and pedagogic problems. Both formal and informal methods should be used. Cultural and resource problems often prevent observation of teaching. Further efforts should be made to introduce this at all levels but it is essential for new entrants to the teaching profession to have support, including observation of their teaching, from more experienced colleagues. Other ways of monitoring the process include student feedback and regular self-critical planning and review meetings by the staff. The student feedback need not only be in the form of fixed-response questions but should include regular interviews and discussions on an individual basis. Students should also be represented at meetings of the course team and faculty board.

Outputs include examination results, comparison with national data, employers' views of graduates, graduate destinations, graduates' views after experiencing employment for some time (one year and five years—an alumni organization can be of considerable help in this respect), reports from examiners, particularly if there are external examiners, from inspectors and from professional bodies.

External assistance with self-evaluation cannot be achieved by documents alone. There should always be a visit by peers as part of the quality assurance process. The first stage must be a document reporting the self-evaluation and this would include the course description mentioned. One or more visits can then follow. These visits should not only consist of round table meetings to discuss the documents with the evaluators and course team but also should include opportunities, formal and informal, to meet teachers, students, employers, support staff. These meetings are more successful if they are held where the teaching and learning is done, close to laboratories, workshops and libraries. The external experts should certainly visit these facilities and they should feel free to act rather as financial auditors do when carrying out an audit. That is, they can ask to see papers, such as minutes of a course team meeting, reports of examiners, examination questions and statistics, and so forth.

There are three stages to any evaluation. Before starting it is very important that the purpose of the evaluation is clear to all those involved. Any evaluation must conclude with a report and it is important to know before starting who has commissioned the report. It is also important before starting to agree on the procedures and methods for the evaluation, the costs and the timetable.

During the evaluation it is important that it should be open and non-confrontational. Agreement and understanding of the purpose by all concerned should achieve this. Small meetings in various settings also help to achieve the openness which is required. If the interaction between evaluators and evaluated is confrontational then it is unlikely that the evaluation will succeed. The evaluated will "close up" and possible withhold information, and certainly they will not easily accept and act on the findings.

After the evaluation it is important for there to be rapid feedback. It is common to give informal oral feedback immediately. There should also be review meetings as soon as possible after the evaluation is over so that both the evaluators and the evaluated can reflect on the process and learn from it. These reflections can then be fed back and included in the training courses for evaluated and evaluators.

Summary

- Higher education is accountable to government, students, employers, and the profession.
- The approach to evaluation depends much on its purpose. There are three main purposes: financing and planning, certifying, and improving.
- The approach to evaluation also depends on what is being evaluated: teachers, courses, departments, faculties, or institutions.
- Quality assurance in higher education must be based on self-evaluation.
- Evaluation requires staff development.
- International agencies should assist with the self-evaluation and staff development.

John Sparkes

Quality in Engineering Education

Mission Statements and Educational Goals

Before any assessment of an educational program can be made it is essential that the intended educational goals have been clearly stated. So it is first necessary to consider how a worthwhile set of educational goals can be arrived at.

It is usually best to begin with a mission statement which establishes the mission of the department or educational institution. Mission statements declare the long-term overall aim of the department—whether it intends to produce vocational courses and prepare people for particular industries, or whether it intends to produce engineering scientists, or flexible engineers, capable of adapting rapidly to new jobs. All these, and others too, are legitimate missions for engineering degrees. And since the educational programs which are appropriate to each particular mission are different, deciding on an appropriate overall aim is not a trivial matter. In general it calls for consultations not only with educators and engineers but also with the customers who may be thought of as the students themselves, or the government of the country concerned, or local industry, or all three.

In developing countries it seems that the appropriate missions for engineering departments in institutions of higher education are not significantly different from those of the more developed nations. For example, although to begin with, a local engineering firm may engage experienced consulting engineers from more advanced countries to help with large projects, it needs to build up its own successful experience as rapidly as possible so that it can handle significant projects itself and accept consultancy contracts without external support. So the engineering education for local engineers should be of the same kind as that in other countries, though the appropriate specializations may differ according to local conditions. Also the proportion of specialist engineers to more generalist ones may need to be different, but there is little doubt that both are necessary.

Once a mission statement has been agreed and accepted, it must then be translated into educational goals, which themselves must be meaningful in terms of their educational implications. That is, the institution or department must be clear about the educational environment it needs to create in order to enable students to achieve the stated goals. Different educational aims demand different educational facilities and methods, so the resources and abilities of the staff must be matched to the stated goals.

Bloom's *Taxonomy of Educational Objectives* (*1956*) was probably the first systematic attempt to achieve a classification of educational goals, but the categories it contained were related more to tests of performance than to educational methods. More recently the significance of 'deep', as distinct from 'surface' learning has come to be appreciated, and the educational methods for achieving them have been realized. These terms 'deep' and 'surface' are derived from the work of Marton and Saljo (*1976*) who referred to the 'deep approach to learning' as the intention to understand and to look for meaning. This contrasts with the 'surface approach' which is concerned with simply memorizing information and practicing skills. The distinction they made was between students' different approaches to learning, but it is of course immediately reflected in the kind of learning which takes place, and evidently calls for a taxonomy which distinguishes among 'understanding', 'knowledge', and 'skills'. 'Deep learning' is therefore another way of referring to learning to think, or to conceptual learning, or to learning to understand, and is a key educational aim in the formation of professional engineers.

In Bloom's taxonomy the concept of 'understanding' was subsumed in high level intellectual skills, such as analysis, synthesis, and evaluation, mainly because it is not easy to identify good performance criteria for testing students 'understanding'. Indeed since Bloom's taxonomy was based on behaviorist psychology the concept of 'understanding'—which is absent from Behaviorism—could not figure in it. Nowadays it is appreciated that the difficulty of assessing 'understanding' is less important than its educational and professional significance. For this reason, the three-element taxonomy in the cognitive domain, of knowledge, skills, and understanding is now seen to be preferable as a basis for specifying educational goals to the more complex taxonomies of Bloom, Gagné and others. It is a further simplification of the taxonomy due to Gagné and Briggs.

The purpose of the taxonomy is to identify and specify the educational goals appropriate to the accepted mission statement(s). Depending on the kind of mission statement arrived at, the content of a degree course can be general or specialized in a particular engineering field. It can concentrate on fundamental principles or give up-to-date information about the state of the art in the subject: it can be mainly vocational or have a strong emphasis on engineering science, and so on. These different overall aims can be quite simply analyzed into the categories of knowledge, skills and understanding within particular subject areas. The main advantage of doing so is that the business of identifying appropriate forms of teaching then becomes a fairly straightforward matter. But first it is necessary to be clear about the nature of these three educational concepts—especially since the words 'knowledge', skills' and 'understanding' are used very loosely, and sometimes even interchangeably in everyday language.

Knowledge, Skills, and Understanding

The need to define these three terms is analogous to the need to define such terms as 'work', 'energy', and 'force' in science, since these are used just as imprecisely in everyday language as are 'knowledge', 'skills', and 'understanding'. Scientists have therefore given such terms much more exact meanings for when they are to be used in science. The next few paragraphs similarly attempt to clarify and give precision to the concepts of 'knowledge', 'skills', and 'understanding' as they are used in this discussion.

It is worth noting also that the term 'teaching' is best thought of as "the business of providing educational environments in which students can learn effectively". It is therefore a much wider concept than, say, simply being able to lecture well. It refers to giving tutorials, to designing laboratory activities, to using computers for educational purposes, to running problem classes, to producing educational texts and videos, wherever they are appropriate and effective at helping students to learn.

Knowledge

Knowledge is here regarded as information that has been memorized and that can be recalled in answer to a question. So the 'information' in books only becomes 'knowledge' once it is well remembered. Knowledge is best 'taught' by presenting information in the most appropriate form, by making it relevant, by teaching study skills, and by frequent testing. Some measure of prior understanding in the learner is of course needed: at least it is necessary for learners to comprehend the meanings of the words used to express the knowledge. Knowledge is tested by asking questions which can be answered correctly or incorrectly by simple recall. If students are interested and understand the meanings of the words and images to be remembered, their learning can be almost instantaneous.

Skills

Skills are here defined as the ability to do specific things without necessarily being able to understand the processes by which one does them. Examples include many of our everyday activities such as speaking, writing, designing, doing elementary mathematics, playing tennis. Although such acquired skills are clearly stored in the memory in some way, they cannot be 'recalled' in the same sense that knowledge can be. Nor can they be learnt almost instantaneously, however interested one might be in acquiring the skills. That they have been learnt successfully can however easily be tested by setting tasks that require the exercise of the particular skills.

Manual or motor skills need not be distinguished from intellectual ones (as they are in Bloom's taxonomy), because their learning is no less a mental activity than the learning of intellectual skills, and they are learnt in much the same way. That is, they are taught by instruction and demonstration, followed by the provision of plenty of opportunity for practice—preferably, though not necessarily, monitored by a teacher or demonstrator. Since it is a great deal easier to know how to do something than to be able to do it well oneself, a good deal of self-monitoring of skills is possible.

The term 'skill' is often also used more generally to embrace the idea of 'capability'. For the purposes of this report, however, it is necessary to keep them separate. 'Capability' is here thought of as a combination of knowledge, understanding, and skills, usually in a particular field of activity. The difference between 'skills' and 'capability' can be illustrated by comparing, on the one hand, a 'skilled' television service technician, who has been taught how to correct a number of specific faults, but may not be able to deal with unexpected ones, with, on the other hand, a 'capable' engineer who understands how television sets work and can think out what the cause of any fault must be—and then be able to put it right. The, capable person can analyze, synthesize and evaluate as well as implement changes. Whilst the technician may well be quicker and more 'skilled' than the latter with recognizable faults, the latter must be regarded as more 'capable'. Indeed the difference is essentially the same as that between 'surface' learning and 'deep' learning described earlier.

Understanding

Understanding involves grasping concepts and being able to use them creatively. There are many levels or degrees of understanding. At the simplest level it involves grasping such concepts as 'table' or 'red' so that a sentence such as "that's a red table" is meaningful, and so that one can create such sentences for oneself. (It is sometimes helpful to refer to this level of understanding, which is mainly concerned with the meanings of words, as 'comprehension'. It is obviously an early stage in the development of fuller understanding.) At its most advanced level, understanding involves grasping advanced academic concepts whose meanings cannot simply be taught by pointing to instances and counter-instances, as can everyday concepts.

In engineering, for example, such concepts as energy, magnetic fields, centrifugal forces, quality, and productivity are a vital part of capability, but cannot be 'pointed to' or ostensively defined in any clear way. Nevertheless, understanding, based on such concepts, is needed in the design and production of new products, in the explanation of new phenomena, in the diagnosis of causes of failure, in the ability to tackle new projects sensibly and successfully, in the ability to ask searching questions, in being able to make good decisions based on incomplete data and knowledge, and so on; all of which are essential engineering capabilities.

It seems that to teach understanding it is usually important to create a 'rich learning environment'. For small children who are learning the meanings of everyday concepts, guided exploration in a rich everyday environment is important. More advanced concepts are then taught in school and are developed further in higher education. Discovery-learning or 'guided exploration' is less successful with advanced concepts if only because their creation in science and engineering, for example, was the work of geniuses such as Newton and Lord Raleigh. So it is not to be expected that students will normally be able to discover them for themselves. Indeed most people find advanced concepts difficult to grasp. They cannot be memorized like knowledge or acquired by practice like skills. Even having them defined and explained is rarely enough to enable people to use them creatively themselves. Although abstract concepts can be grasped in due course by, say, reading a good textbook, most people are helped by a more active kind of learning in which the concepts are exercised, discussed, applied, read about, written about, asked about, used in designs, and so on. Hence the need for a rich educational environment.

Concepts can also be grasped through the experience of using them continually, for example through apprenticeship training. Although this a rather slow process, and not really practicable in educational institutions unless the aim is for very specialized training, students can acquire a kind of tacit understanding of complex processes through such experiences. The method is, of course, always included in medical courses, where the focus of attention, namely human beings, is very clearly defined.

To test for understanding in engineering it is necessary to set students new challenges and see how they use the important engineering concepts in tackling them.

Discussion

The three kinds of learning in the cognitive domain just described differ considerably in how they are learned, how they are best taught and how student learning is best tested. Table 2.1 summarizes these differences under the headings of the kinds of resources they require, the educational processes they entail and the assessment methods that are appropriate. The table also includes, for completeness, comments about the 'affective' domain of learning. In practice it seems that the factors which affect attitudes, values and personal qualities—especially motivation—need to be borne in mind in designing the educational methods to be used to meet the stated cognitive educational goals.

Table 2.1: An Analysis of Engineering Education

Quality Pparameter Type of Learning	*Resources*	*Process*	*Assessment of Outcome*
KNOWLEDGE	Provide information in best way (lectures, data bases, video or audio tapes, books).	Show relevance of information to experience. Teach simple study skills. Use discovery methods where appropriate.	Test for recall by questioning.
SKILLS	Provide facilities appropriate to the skills being learnt (labs, problem classes, computers, group projects).	Instruct and demonstrate the skills and make opportunities for practice - often, but not necessarily, supervised.	Set tasks that require the exercise of the skills.
UNDERSTANDING	Provide a rich educational environment (lectures, labs, computers, library, tutorials, coffee bar, VCRs, problem classes, electronic mail). Further education for staff.	Focus teaching on concepts. Encourage students to use as many facilities as they can to help grasp new concepts. Set projects. Add problem-solving to all lab experiments.	Set new tasks that require understanding, not just skills and memory, for their completion (projects, open-ended questions, correcting other peoples' errors, designing, explaining).
ATTITUDES, VALUES AND PERSONAL QUALITIES	Provide congenial surroundings and good quality teaching methods, and counselling. Provide newspapers, discussion groups, external contracts.	Motivate where necessary (in lectures and visits, by example, by teaching Learning to Learn, by setting challenges that can be met successfully, by counselling).	By personal contact, by the effort exerted, by the extent to which challenges are welcomed, by the questions asked, by breadth of outlook, by enthusiasm.

Because there are differences in the teaching methods which are appropriate to the different kinds of learning, it is clear that it is helpful if the educational goals of a course are specified in terms of these distinct kinds of learning. It is then a simple matter to match the teaching methods to the stated goals. Specialized courses, for example, are likely to be more concerned with specialized knowledge and skills than with understanding a wide range of fundamental principles. Such understanding is likely to be more appropriate to broader courses aimed at producing more adaptable engineers—capable of rapidly applying their hands and minds to new problems as they arise, with a minimum of further training or education.

Thus the reasons for specifying educational goals in terms of knowledge, skills, and understanding as well as attitudes and values can be summarized as follows:

- They facilitate the clear specification of educational goals for different kinds of courses. For example, up-dating courses are mainly about knowledge, training courses are mainly about skills, up-grading courses are mainly about advancing skills and understanding—often for a further qualification, awareness courses are mainly about knowledge and understanding at a fairly superficial level. Undergraduate degree courses are usually about all four—knowledge, skills, understanding, and attitudes—though in a variety of different proportions. Competence courses are like undergraduate courses but are focussed on more particular activities.

- They clarify the ways in which specified goals can be translated into effective educational methods.

- They indicate the methods by which it is sensible to assess student performance against the specified educational goals.

- They create a structure around which it is possible to design a rational procedure for assessing the quality of engineering courses, which involves looking at resources, teaching procedures and outcomes in relation to specified educational goals.

Conclusion

The 'mission statement' about engineering education adopted by an institution of higher education is mainly its own concern. It need not be a matter for external assessment, as long as it is capable of interpretation at an appropriate academic standard. Mission statements are likely to be closely related to local conditions and needs, though it seems that the tensions between the need for specialization and the need for a more general preparation for work in many possible fields of engineering are the same in developing countries as they are in highly industrialized ones. The resolution of the arguments might very well be different however. For example, in developing countries it is to be expected that graduates will rise to management positions more rapidly than elsewhere, a fact which may well affect the mission statements adopted by the local engineering departments, and will certainly affect the educational aims of vocational courses.

However the decisions and actions which follow from an agreed mission statement can very well be matters for external assessment. They can be grouped under four headings.

Assessment of educational goals

Within a specified mission statement, it is necessary to judge the validity and standards of the educational goals that the institution has specified. They should be comparable with those of other nations if they are to be internationally recognized. The goals need to be specified in terms of the knowledge. skills, understanding (and attitudes) to be expected of students. Note that other terms such as factual knowledge, fundamental principles and their application, are equally valid as long as their meaning is made clear.

Assessment of process

The educational methods employed, the resources provided and especially the examinations and other forms of student assessment used, should match the stated educational goals. Table 2.1 summarizes the kinds of activities to be looked for.

Assessment of outcomes

As usual, student performance, as measured by examinations and other forms of assessment, needs to be monitored.

Assessment of quality control procedures

At present the standards and quality of courses offered by institutions of higher education are either assessed externally by bodies such as councils for academic accreditation, or else the institutions are relied upon to maintain standards through their own internal procedures. Often these procedures are very informal and based on little more than the intuitive judgement of the teachers. There is a need therefore to assess, or at least review from time to time, the procedures for quality assurance that an institution adopts.

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Ton I. Vroeijenstijn

Reviewing Quality

One of the problems in a discussion about quality and quality assessment is the question "What is quality?". Quality is like love. Everybody talks about it. Everybody knows and feels when there is love. Everybody recognizes it. But when we try to define it, we are at a loss. In literature we can find several descriptions of the concept of quality. "Quality is determined by the degree to which the previously set objectives are met" (De Groot 1983). Sometimes quality is defined as "fitness for purpose" (Ball 1985). Quality is also defined in terms of added value (McLain and others 1989).

Often it is said that quality is the satisfaction of the client or the user. But this definition leads to problems. When we talk about the quality of a personal computer, it is clear who the client is. But that is not the case with education. Who is the client? There are a number of clients and a number of users: the students, of course, but also the employers, and the society in general. The expectations of quality held by the various users can run parallel, but they can also conflict.

The quality of education, viewed from the perspective of the 'customer', for example the labor market, means first of all, the standard of the graduate. A student, on the other hand, will define quality in terms of the structure of education and the way in which it is presented. From the point of view of the discipline, quality will be related in the first instance to the standards set for graduates and to the expectations of the students, but there will, in addition, be specific requirements, for example that the education must link with recent academic developments.

The conclusion must be that we can not talk about the quality of education. We have to speak about qualities in the plural, or aspects of quality. It is a waste of time to look for a definition of quality, but it is necessary that all parties concerned made their expectations explicit. In assessing quality and working toward the improvement of quality, all these requirements should be taken in account.

Can Quality Be Quantified or Standards Set for Quality?

With reference to an evaluation of quality two questions are of importance. The first question is: can quality be quantified? Opinions are divided. It is evident that, where people try to derive quality directly from quantitative data, differences of interpretation will arise. Consider, for example, the measurement of the quality of research. Is the total number of publications a true measure of quality? The analysis of information and experience gained elsewhere indicates that this is not unequivocally the case. Another example which refers to education is the interpretation of pass/fail data. Is a high success rate an indication of quality, or of reduction of standards?

The problem concerning the quantification of quality makes it necessary to consider quantitative and qualitative data interactively. Conclusions cannot be drawn from quantitative data on their own. The results must first be the subject of discussion and dialogue.

The second question is: can standards be set for quality? It will already be clear that it is not quality as such, but rather aspects of quality which should be discussed; and, where there are different demands and stakeholders, it is impossible to speak of one set of norms. There are several systems of standards and criteria against which quality has to be evaluated.

Quality control must have an anchor point. Standards and criteria can be derived from the objectives and the demands which are required by those who pay attention to quality. This means that the government will formulate different standards and criteria than, for example, the employers will. And just as the requirements made with respect to the quality of education can diverge, so can the standards which are applied to measure it.

Although it remains necessary to strive for a good description of quality and aspects of quality, the lack of a definition may not be an excuse not to pay attention to quality.

Basic Principles for Reviewing Quality

From the heavy emphasis on quality in the last decade it would seem that higher education has never had an interest in quality. We all know that is not true. Academic staff, departments and faculties have always paid attention to quality and quality improvement. But the attention was ad hoc and unsystematic. The best way to guarantee quality is by a system of quality control. That is to say, systematic and structured attention to quality, aimed at warranting and improving quality. Thus, a quality system needs a good organizational structure, clearly defined responsibilities, clear processes and procedures for quality assurance.

In setting up a good system for quality control or quality assessment it is necessary to take into account the following principles:

- Quality control and quality assessment are the responsibility of institutions of higher education. They do not leave these responsibilities to an outsider such as government or an inspectorate.
- The primary purpose of quality control should be improvement.
- Quality control has both internal aspects (self-assessment) and external aspects (peer review).
- Self-assessment is the cornerstone of the system.
- Peer review is conducted by unbiased experienced peers, some laymen, and representatives of the labor market.
- The measures of quality are both general quality standards, and the achievement of stated institutional or program goals.
- Assessment is regular and cyclical.
- The assessment process must have consequences, with the study and visits resulting in action.
- Systems of external evaluation designed to provide public quality assurance should be accountable to the public they serve.

The Aims of Quality Assessments

The aims of quality assessment are as follows:

Quality improvement

Quality assessment is first and foremost aimed at discovering weaknesses and enhancing and improving quality. In the first instance, this takes place in the critical self-assessment of the faculty or institute. Peer review is an additional tool for internal quality assurance, because problems can be discussed in the dialogue with the external experts. The discussions and interviews are the bases on which the committee will formulate recommendations for improvement.

Self-regulation based on quality.

In the past, governments have thought it possible to set higher education in the right direction by interference. State regulation was the answer for the development of the university system. The new philosophy of more autonomy, seen at the moment in several countries, means the substitution of detailed regulation beforehand by control afterwards and the creation of boundary conditions. Self-regulation should increasingly take the place of state regulation.

Self-regulation must be based on a good system of quality assessment and quality assurance. In the first place the faculty have to decide upon their mission and the possibility of reaching it. The outcome of the self-assessment and the recommendations of the peer review should be discussed by the faculty. What can be done to improve the weak spots? What can be done with the recommendations concerning goals and aims?

But the faculty can not do the job by themselves. The university as well should have a good system of quality assurance and self-regulation. The university board should open a dialogue with the faculty concerned, based on the results of the past quality assessment.

Accountability to the public with respect to the quality of education.

Quality control means not only giving a warrant for quality, but also accountability to society. The committees of external experts play an important role with regard to accountability. The committees study the self-assessment of the faculty and have a discussion with faculty staff and students. In their reports the committees give a 'certification' of the stated goals and the capability of the faculty to meet them. There will also be a certificate for the system of internal quality assurance.

A System of Quality Control

As said, the best way to guarantee the quality is by systematic and structural attention to quality enhancement and improvement in a good organized system of quality assessment. The system should have the following elements.

The goals of the institute or faculty are the frame of reference for quality assurance. They must be formulated clearly and meet scientific and societal requirements.

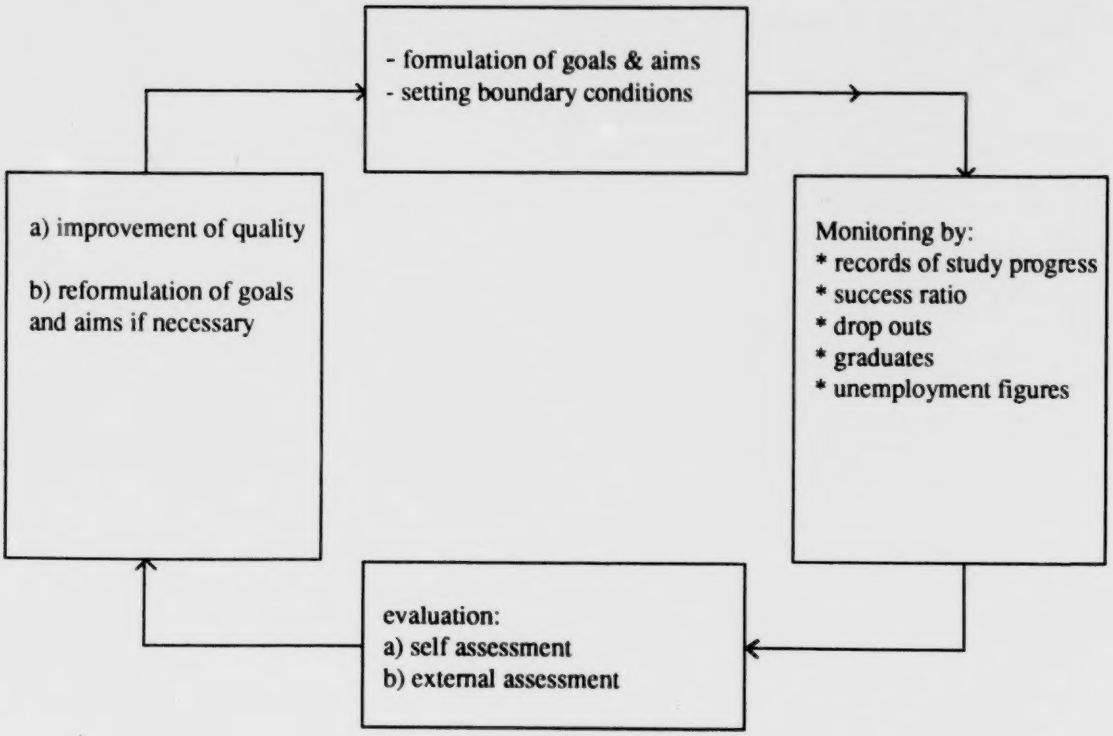
All too often the boundary conditions are forgotten in the discussion about quality assessment, but quality is affected by boundary conditions, for example those set for institutes of higher education by government. If a school is allowed to select the students at entrance instead of being forced to take in everybody as in the Netherlands, it is easier to deliver quality. If a school conducts its own personnel management, it is better able to manage quality. Financial conditions are also important. Too often people forget that quality has its price. Considering the price of a Skoda or a Lada, the same quality cannot be expected as from a more expensive Saab. In the same way institutes of higher education cannot be expected to maintain quality in the face of dwindling money resources and increasing student numbers.

Every institute or faculty must set up a good monitoring system. This contains, for example, the records of study progress, success ratios, drop-outs, graduates, (un)employment figures. These indicators can be used to follow input, process, and output. The realization of the goals can be measured at any time, and the faculty can keep a finger on the pulse and take action whenever necessary.

Evaluation is the most important link in the process of quality assurance. At regular intervals, there must be a critical self-assessment, whether or not followed by peer review.

The results of the evaluations and analyses of strengths and weaknesses should lead to measures for the improvement of quality. The bottlenecks and weak points which are identified must be eliminated, or goals reformulated if necessary. The introduction of these elements into the system is presented schematically in the following diagram.

Figure 3.1. A System of Quality Control


- formulation of goals & aims
- setting boundary conditions
Monitoring by:
* records of study progress
* success ratio
* drop outs
* graduates
* unemployment figures
evaluation:
a) self assessment
b) external assessment
a) improvement of quality
b) reformulation of goals and aims if necessary

As already said, quality control has internal and external aspects—self-study, and peer review by a visiting committee. The external quality assessment is never an end in itself, but rather an extension of the internal quality control. The link between external and internal quality control is the self-assessment of the faculty.

A competent self-evaluation process will address the following questions.

- What are the objectives? Are they clear, complete, appropriate, and useable? Is there internal consensus concerning their interpretation?

- Are the educational programs related appropriately to the objectives? Are programs set up with achievement of the objectives in mind? Does it appear that they work well? Do any problems arise with their implementation? How can any problems which arise be resolved?

- Are there adequate means available for the implementation of the programs and services?

- To what extent are the objectives achieved? How can systematically collected data relating to the extent to which objectives are achieved be used? What is the significance of the data?

The self-study must be not only descriptive, but also analytical. It includes an evaluation of the problems, and an indication of how the problems identified will be dealt with.

The self-study forms the starting point for the discussions between the visiting committee and the faculty. This implies that everyone who will be concerned with the discussions needs to be aware of the contents of the self-study.

In the guide for external program review a checklist for the self-assessment is given (Appendix). In this checklist are 'points for attention' which are the questions to be addressed by the internal evaluation. If the checklist is followed carefully, it should be possible to arrive successfully at a good strengths/weaknesses analysis.

Peer Review

Internal quality assessment is followed by external quality assessment, done by peers, also called the visiting committee. In the Dutch situation the task of the visiting committee is as follows:

A. To form an opinion on the basis of information supplied by the faculty and by means of discussions held on the spot about:

  - The standard of education.
  - The quality of the educational process.
  - Organization.
  - The standard of the graduates.

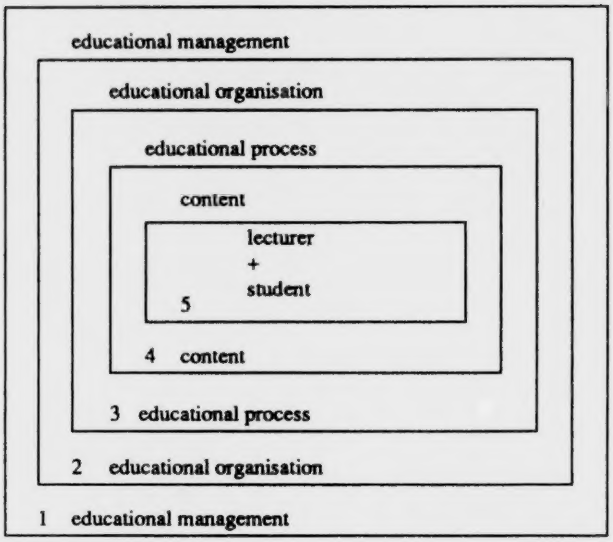
B. To make suggestions on quality improvement.

In noting that the committee is requested to form an opinion, the concept 'form an opinion' should not to be interpreted as 'sitting in judgment' and handing out a sentence in terms of 'good' or 'bad'. Neither is it a matter of approval of an educational program; the committee is not involved with accreditation or program recognition. The aim of the visit is rather to follow up, through dialogue with the faculty, the points of strength and of weakness indicated in the self-study. The committee can, as a group of expert outsiders, hold up a mirror to the faculty. The fact that the committee does not pass a sentence is not to say that it cannot make critical comments. Obscure or cryptic language should be avoided. What is needed is fair criticism without sentence.

The starting point for the committee is the list of objectives which the degree program has formulated for itself. Here it is impossible to evade the question as to whether these objectives conform with those generally accepted to be appropriate for a particular program, certainly when the programs concerned have a civil effect, be it on the ground of legal provisions or in actual fact. The scholarship of the educational program should not escape attention, and comparisons with courses abroad will also have their place.

At what does a visiting committee look? The different factors which determine the quality of the educational program can be represented as a series of concentric layers, as in the following diagram.

Figure 3.2. Determining Factors of the Quality of Education


educational management
educational organisation
educational process
content
lecturer
+
student
5
4 content
3 educational process
2 educational organisation
1 educational management

In the first place the quality of an educational program is strongly dependent on the quality of the lecturers and the manner in which knowledge is transferred. This is difficult to judge at first hand without spending a great deal of time in lectures and seminars. Indirectly, an opinion can be formed by drawing on the comments of students, the extent to which the lecturers are able to receive didactic training, and the extent to which didactic qualities are taken into account in the appointment and promotion of staff.

The quality of the educational program is further determined by the content and the level of the subject matter taught. The content is strongly dependent on the objectives, and the manner in which these are translated into final student assignments. To a certain extent the course description gives some insight into the course content. Questions which can be asked are related to the consistency of the program, the underlying philosophy (why has this program in fact been chosen?). Are the program elements necessary for practice in the professional field included? Does the program conform with recent developments in the discipline? Is the educational program of a sufficiently high scholastic level? Does the content of the educational program satisfy the requirements of occupation and profession?

In order to form an overall view of the educational level of the program the committee members will have to continue to collect and place together the separate pieces of a jig saw puzzle. The necessary knowledge can be accumulated from the study of the literature lists for the first year (propaedeutic) and degree (doctoral) phases, master theses, test and examination questions, and course descriptions and readers.

The experts in the committee are expressly chosen so that, on the basis of the available information, they will be able to form a picture of the content and level of the educational program in a very short time.

The Educational Process

Other than through the direct transfer of knowledge, content and level, the quality of the educational program is also determined by the educational process. Apart from considering an individual teacher, it can be seen whether in general the most appropriate instructional methods are used for transfer of knowledge to the students. Has the program been so set up that it can be completed by a student in the prescribed time without too many difficulties? Are there unnecessary bottlenecks? Does the program match up with the reasonable expectations of students?

Educational Organization and Educational Management

The given restraints and educational policy also determine the quality of the educational program. What are the conditions under which the degree program must give shape to the educational process? What is the relationship between teaching and research? What is the study load? What policy is followed with respect to education? An important aspect of educational organization and management is the structural quality control. In what ways are these attended to? What is done as a result of evaluations?

How deep should a committee dig? Taking into account the restraints within which the visiting committee has to work, there is conflict between taking a deep look at the educational provision and getting to the core of the matter, and on the other hand looking down from a higher level of abstraction (educational process, educational organization, educational management). The expectation is that if the first four layers are peeled off and look healthy enough, and certainly if a glimpse of the fourth layer can be seen, then it can be assumed that the quality will be good. Should the first layers display some bad or rotten patches, then, even if it is only possible to drill down and take a sample, the committee will in any case have to get to the heart of the matter.

Does It Work?

The most important point about quality review is its effect. Anyone who wants to evaluate the quality assessment using only the self studies and the reports of the committees, is making a mistake. The reports are important, but they are only the tip of the iceberg. The process of quality assessment is far more important. A lot is happening which will never be found in the reports. It is known that faculties sometimes start with self evaluation long before the formal announcement. There is already quality enhancement before the self-study report is written, but you will find no trace of it. The mere fact that a visiting committee is announced already has a positive effect. The faculty wants to clean up the house before the committee arrives.

Just as the process of self-evaluation is more important than the self study report, so also the actual visit is more important than the report of the visiting committee. When the faculty members meet the committee for the first time, they are a little tense. Often they still have the idea that the visiting committee come as inspectors instead of as peers. But usually after the opening address of the chairman of the committee, the ice is broken. The faculty members like to discuss educational problems with the members of the committee. They like the dialogue with expert colleagues. The discussion is very open. The faculty often say it was a hell of a job and self-evaluation takes a lot of time, but it was all worthwhile.

Engineering Education in Developing Countries

Can the experiences in Dutch universities be applied to engineering education in developing countries? Since most developing countries are, with regard to quality assessment, in the same situation as the Dutch universities before 1985 (that is to say attention to quality is unstructured and unsystematic), the system is useful. Of course it must be adapted to the local situation, but the basic principles will work.

In the Netherlands the external quality assessment is conducted nationwide, that is to say all universities with the same program are reviewed. But the system of self-assessment and peer review can also be used by a single department. The most important steps are:

- To stimulate the department to set up an internal quality system, making clear where the responsibilities lie.
- To introduce the techniques of self-assessment and the self-study report.
- To set up the peer review, taking care that the external committee does not act with conflicting purposes: for example, accountability for expenditure is difficult to combine with quality improvement.

Finally, we should not forget that quality, just like love, is more a question of attitude and favorable disposition than a matter of systems.

Appendix

The following is a translation of the guide developed by the Association of Universities in the Netherlands for self-assessment by faculties and committees.

CHECKLIST FOR SELF-ASSESSMENT

(In: Guide to external program review, VSNU, 1989)

Chapter 1. The place in the organization

- The discipline-oriented approach of external quality assessment does not always correspond to the way in which the unit to be visited fits, in organizational terms, into the university organization; it is therefore desirable to begin the self-study with a chapter describing the specific organizational structure and the position of the faculty/discipline within the university structure. The departments involved in designing the program should also be listed.

- Which committees are involved in the discipline? What are their tasks and how are they made up?

Chapter 2. The students

- The size of the student intake.

- The characteristics of the student intake (sex, age, geographic origin, previous education/professional experience).

- The prevention of and problems with deficiencies; problems with previous education.

- Activities related to information and recruitment.

- Intake trends in recent years; significant shifts in the intake.

- Success rates of the propaedeutic and the degree phase.

Chapter 3. Brief description of the programs

General

- Have objectives been formulated?

- Has the required level of ability and knowledge among graduates been laid down?

- Do the objectives differ according to the programs?

- To what extent do the objectives differ from those of similar programs at other universities?
- To what extent are the objectives achieved?
- Are the objectives still appropriate in changed circumstances?
- Are there plans to modify the objectives?
- Are there plans to profile the program or strengthen its current profile?

The propaedeutic course

- What is the general structure of the propaedeutic stage? Which subjects are taught? What are the relative proportions of the subjects?
- Are there requirements in terms of a mutual relationship between the subjects?
- Does this propaedeutic stage differ from that of other institutions?
- Which subjects play a role in the orientational and selective function of the propaedeutic stage? What is the assessment of the orientational, selective and referral function?
- Is the propaedeutic stage unsatisfactory in the light of the follow-on courses?
- What were the grounds for choosing this structure for the propaedeutic stage?
- Have there been structural changes to the course in recent years?

The degree phase

- How is the degree phase organized? What is the relation between joint courses and main subjects? Which main subjects are available?
- How, in general, are the various main subjects organized? What are the core components of the program and what are the optional components?
- What is the extent of the fixed program? What is the variation in optional elements? The profiling of the various main subject vis-a-vis other institutions; what led to the decision of profile a particular main subject? Does the profile meet the expectations?
- Are there problem areas in the main subjects?
- Organization of practical work, projects and master thesis.

Other courses offered

- Postgraduate courses (vocational and teacher training).
- So-called short courses.
- Service and contract courses.
- Research assistantship.
- How many students go on to postgraduate study? Does the standard of postgraduates meet expectations?
- Experience with service and contract course.

Part-time programs

- Are part-time courses also offered in the program?
- If so, how does the part-time program differ in terms of material and structure?

Chapter 4. The educational process

- What forms of teaching are used in the acquisition and transfer of knowledge (scope of lectures, organization of seminars, tutorials, practical work, etc.)?
- How is the computer used in the courses?
- In terms of educational theory and didactic, is the program designed in such a way that it can be completed in the allotted time without too much difficulty?
- Are there specific problem areas, for example, the transition from a structured propaedeutic stage (or basic course) to the degree phase (or graduation phase), student traineeships, writing a master thesis, final paper?
- How are students assessed? a) in what way (multiple choice, open questions); b) when (sessional, finals)?

Chapter 5. Program organization and program

Educational policy

- How is the educational policy formulated? Which committees are involved?

- Is the policy relating to the discipline linked to the institutional policy? Connection with development plans?

Personnel policy

- What is the policy in respect of the ratio of teaching to research? How large is the teaching load?
- What is the policy in respect of deploying staff in the propaedeutic course and the main subjects?
- What is the policy in respect of staff development in seminars, supervision of master thesis, practical work and/or work experience?
- Are there factors which make it difficult to pursue a good personnel policy?

Internal quality management

- How is attention given to internal quality management? Is there systematic evaluation? Which evaluation system is used?
- How is educational innovation handled? How is education support organized?
- How is attention given to the professionalization of the staff (management courses, educational/didactic training)?

Study progress, study supervision and study counselling

- Have the study hours involved in the propadeutic course and/or the degree phase been measured in recent years? If so, what were the findings?
- Have the results led to changes in program design and/or study supervision?
- Is the study program recorded? Do these records lead to the early recognition of problems and to remedial and/or preventive actions aimed at the individual student or program design?
- Has there been an investigation into the reasons for exceeding the terms of enrolment? If so, what were the findings? What were the resultant measures?
- How is study counselling organized and what is its effect?
- How is study supervision organized and what is its effect?
- Program information: (a) for prospective students; (b) during the program; and (c) as preparation for entering a profession?

Facilities

- Educational facilities (lecture halls, areas for practical work, etc.); the situation in respect of laboratories.
- The situation in respect of libraries.
- The situation in respect of computer equipment.
- The size of the budget for facilities.

Interaction between central and faculty level

- How is the interaction organized between the faculty or discipline and the executive board of the university in respect of education and, in particular, of promoting quality? How does the faculty's educational policy relate to the institutional educational policy? Does the faculty profit from facilities provided by the central level for promoting quality?

Chapter 6. The graduates

- Do prospective employers set standards which the graduate must meet? Can the future profession be clearly defined? Have these definitions changed over the years?
- Where do the graduates end up?
- What is the unemployment rate among graduates?
- Are there contacts with alumni?
- How do the alumni regard the program?
- Are contracts with prospective employers structural or incidental?

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T.P. Melia

Guidance for an Evaluation Committee

The objectives of this discussion are threefold:

- To describe how the English evaluating agencies (the institutions, the examining, validating, and professional bodies, and Her Majesty's Inspectorate) go about their work, and to highlight those aspects of their work which are relevant to the tasks of assessment in developing countries.
- To offer an assessment model from which a template might be formed for the use of engineering specialists inspecting engineering education in developing countries.
- To stress the importance of the assessors working closely with the institutions being assessed and gaining their support and confidence.

In the last connection it is essential not to become involved in any form of secret reporting. Reporting should be open and subject to public scrutiny. Only in this way will the assessors gain the confidence of not only the institutions and staff being assessed but also of those outside the cloistered walls of higher education who will watch with interest and, on occasions, skepticism.

Quality and Standards

Quality in education is dependent on many important factors. It has to do with the pursuit of scholarship through teaching, research or study. It's to do with a sense of order and structure; the good lecture has been carefully plotted and organized. It's to do with maximum student engagement; in the good lecture, the students' attention is fully held and their enthusiasm and interest sustained. It's to do with achievement; in the good lesson the students leave enriched having been set, and having achieved, appropriate standards.

Quality is to do with all that which supports teaching and learning. There is quality in terms of teaching: the good teacher has up-to-date knowledge of his subject, is enthusiastic about it, understands how people learn, has attractive personal characteristics, uses a variety of teaching methods, and has high expectations of the students. There is quality in terms of accommodation: the provision of suitable classrooms, workshops and laboratories which are conducive to learning. There is quality in terms of equipment and resources: the provision of well-designed teaching and learning aids, and a library which is well researched, adequately staffed and well used.

Yet, the starting point in the quest for quality must be the actual learning process. It is sometimes possible to achieve good practice in poor accommodation and with poor resources. Ironically, it is also possible for poor or even bad teaching or learning to occur in excellent accommodation and for it to involve good resources; and here the plot thickens for the resources, though good in themselves, have little value in a context where they are mis-applied. And this in turn leads to the conclusion that quality is to do with fitness for purpose, and a chief' prerequisite for quality is the identification of clear and appropriate objectives at the institutional, departmental and course levels.

On the face of it the concept of standards is more straightforward than that of quality. In fact a definition can even be attempted that standards refer to levels of achievement against which performance can be assessed.

Such a definition implies that standards are measurable. But measurable against what? Some absolute standard, academic criteria—and what about values? Again fitness for purpose must be the yardstick against which to judge standards at all levels of education. By way of illustration, England, along with many other countries, is striving to move from an elite to a mass system of higher education. It is evident that no single approach to expansion would be appropriate. A wide variety of institutions is needed offering a range of subjects and courses at different levels, in the full-time and part-time modes and at different costs. In such a higher education system academic standards must be appropriate to both the students and their programs of study. The criteria applied to the traditional elite higher education provision is not an appropriate yardstick against which all higher education institutions or the programs of study which they offer can be judged. Research and scholarship are particularly relevant in this connection. The research and scholarship needs of those teaching in a mass higher education system are very different from those teaching in an elite system.

The attempt to establish standards and ensure quality in English higher education is as follows.

The Evaluation of Quality

The quality of education is important and its enhancement is a major objective of all governments. Quality assurance, quality control and inspection are significant aspects of the assessment, maintenance and enhancement of quality in England. Quality assurance provides users of the education system with a guarantee that institutions, courses and graduates meet certain standards. Quality control embraces the methods used to maintain and enhance quality. Inspection is concerned with standards of learning and is based on the direct observation of students and their teachers at work and involves professional judgement which is collective rather than individual and draws on a knowledge of national as well as regional and local standards.

In England there are many layers, some would say too many, engaged in the evaluation of higher education provision. These include the institutions themselves, the validating bodies, the professional bodies, Her Majesty's Inspectorate, and the universities' Academic Audit Unit.

All have their separate and overlapping functions but all strive to ensure that the quality of higher education in the United Kingdom and the standards achieved by its graduates compare with the best in the world. By and large this is achieved.

Earlier it has been pointed out that the term quality has a meaning only when related to functions such as fitness for purpose. Criteria based on fitness for purpose need to take account of factors which do not lend themselves easily to quantifiable assessment. Herein lies the main problem in assessing quality. The assessment of non-quantifiable variables necessarily involves professional judgement based on wide experience. The various approaches to this task by those engaged in evaluation of higher education in England are described below.

In England it is recognized that the main guardians of standards and quality are the institutions themselves. Universities have always had a right to award their own degrees and are responsible for their own standards. However, in response to criticisms that they do not monitor standards in undergraduate courses sufficiently rigorously, the university vice chancellors have set up an Academic Audit Unit to consider and review the universities' mechanisms for promoting and enhancing academic standards. The Unit hopes to begin auditing institutions in spring 1991.

Since 1964 the Council for National Academic Awards (CNAA) has been the main agency for approving degree courses and granting degrees and other awards in the non-university sectors of higher education in England. Following a review of the academic validation of degree courses in the non-university sector of higher education in 1985 the CNAA in line with the recommendations of the review, devolved responsibility for quality control to institutions through accreditation and association. These arrangements allow mature institutions, after accreditation, to validate, approve and review all their taught degree courses leading to CNAA awards. Other institutions in association with CNAA are allowed to plan the validation and review of their courses in conjunction with CNAA.

In both accredited and associated institutions CNAA requires the academic board to take responsibility for the content, organization, quality and standards of its courses and to ensure that they are adequately researched and controlled. The academic board in discharging these responsibilities requires departments through their course committees to produce an annual course review which deals with curriculum matters, student progression, examination results, external examiners' reports and resource needs. External advice is also sought by the academic board when approving new and reviewing existing courses. The regulations and procedures underpinning CNAA validation of both accredited and associated institutions is given in the CNAA's Handbook.

Sub-degree level work with a vocational slant is validated by the Business and Technician Education Council whose procedures are outlined in their Quality Control Circular 16 issued in 1986.

Professional bodies are concerned with the maintenance and enhancement of progressional standards and the protection of professional interests. In general the professional bodies accept CNAA validation as evidence that appropriate academic standards are achieved. Some professional bodies, however, make their own arrangements to accredit institutions. Professional bodies are usually concerned with course content, the appropriateness of resources, the standard of the final examination and the quality of the preparation for professional practice rather than the learning that underpins the course.

The prime concern of Her Majesty's Inspectorate (HMI) is with standards of learning and their interest in organization and management, resources, quality control arrangements and even the teaching itself derives from the impact they have upon standards of learning. For example, certain sorts of equipment are necessary to ensure appropriate standards of learning in certain aspects of science, engineering, or computing. HMI are not so much interested in the equipment per se but in its role in facilitating learning. The evaluation of learning is their central purpose. It is the role of HMI to report upon the quality of education they see implemented throughout the schools and colleges of the land. The basis of their judgements often lies in comparison. HMI are privileged to see a wide range of provision. They see some educational practice that is excellent and some that is poor and much that lies somewhere in between. To some extent, they define quality as they go. HMI may find tomorrow work of an excellence or inadequacy that they have not yet encountered.

In order to judge the quality and effectiveness of an area of work or course HMI examine first its aims and objectives and then attempt to assess whether or not the organization and management, resources and range and appropriateness of provision allow these aims and objectives to be effectively achieved. Then, and only then, HMI judge whether the aims and outcomes compare with those of similar courses or areas of work and whether they are appropriate.

In a typical inspection HMI seek to evaluate aims and objectives, organization and management, appropriateness of resources, range and appropriateness of provision, teaching and learning, outcomes, quality control and assurance arrangements.

The criteria used by HMI to assess the quality of provision in higher education are set out in the HMI paper 'In Pursuit of Quality: An HMI View'. In the light of the criteria identified in this paper, HMI use five broad grade descriptors to summarize their findings.

- Generally good, or with many outstanding features or with many good features.

- Some good features and no major shortcomings.

- Sound with no significant extremes or good features balanced by shortcomings.

- Some shortcomings in important areas.

- Many shortcomings generally, poor.

The attractions of grades or rating scales to HMI and others are considerable. They facilitates retrieval and analysis as well as improving the validity of generalizations based on a large number of independent judgements. When grades are reported, the institutions inspected and the readers of published reports are faced with clearer messages about the quality of educational provision and response and are therefore less likely to misinterpret HMI evaluations. Furthermore, during inspections the use of a rating scale can encourage individual HMI to focus sharply on qualitative judgements and help a team to come to better collective judgements.

However, there are difficulties and potential dangers in the use of rating scales. HMI are aware of these and strive to ensure that their use of grades does not give a spurious impression of precision that will not stand up to critical scrutiny. It is a measure of the success that HMI have achieved in developing rating scales that they are now widely accepted, even for funding purposes, in the non-university sector of English higher education.

Inspection of Higher Education in Engineering

The inspection methods used by HMI have been fine-tuned over a period of 150 years and their findings generally, and in higher education in particular, are rarely challenged. Because of the high level of credibility of HMI methods and procedures it is worthwhile examining them in detail and considering whether or not they might be modified to suit the needs of a team visiting an engineering department in a third world country to assess the effectiveness of the education and training provided.

In inspecting higher education in engineering in an engineering faculty of say 60 staff and 800 students, HMI would send in a team of about five engineers whose specialist interests would cover the range and balance of work in the faculty. One member of the team is designated the reporting inspector whose task it is to liaise with the college, make the arrangements for the inspection with them, and devise an aide memoire for use by the team during the inspection. Prior to the inspection the reporting inspector visits the college to discuss the inspection with those to be inspected, indicate the aims and objectives of the inspection and the documents that the team will wish to see both before and during the inspection. An inspection team meeting is normally held in the week prior to the inspection to discuss strategy and assign specific tasks to team members.

During the inspection, which normally lasts for one week, HMI visit lectures, practical laboratory and workshop sessions, tutorials and seminars and inspect student written work, projects and other assignments. Discussions are held with academic and support staff, students and representatives the local community including employers. Throughout the inspection HMI discuss their assessments with those being inspected—the Doctrine of No Surprises. At the end of the inspection the HMI team meet and agree their main findings which are conveyed to the appropriate staff, including the head of the institution, before the team leave.

After the inspection it is usual practice for HMI to meet the governing body of the institution. Following this meeting a report is issued generally within two months of the end of the inspection which is made available to the institution 14 days before it is made public. The institution is expected to respond to the report and outline the action it is taking to tackle deficiencies identified within three months of the report's publication. Follow-up visits to monitor the action taken are made by individual HMI in the following year.

A full account of HMI methods and procedures is given in the document 'Reporting Inspections'.

Messages for a Donors'-Lenders' Visiting Team

Inspection, auditing, evaluation—whatever it is called—has no value if carried out without any reference to the policy framework within which an aspect of education is being conducted. It is essential that the visiting team are aware of the main thrust of the developing country's policy in relation to engineering education and, assuming it is a sensible policy, to assess whether the aims and objectives of the institution or department being evaluated are consistent with national policy. If not, the team should investigate why not.

The team also need to:

- Define clear aims and objectives for the evaluation exercise and make these known to the institution.

- Have a clear evaluation strategy which is faithful to the team's aims and objectives, but is not constrained by them.

- Emphasize to the institution that the prime concern is with the standards of learning and the quality of the student experience in relation to the institution's aims and objectives.

- Agree with the (government or institution or department) the arrangements for reporting and to whom.
- Make clear the criteria underpinning the judgements made—the HMI paper "In Pursuit of Quality" should be helpful in this connection.
- Gain the support of institutions and their staff.
- Convey clear and unambiguous messages.

In doing all this, process and outcomes need to be examined as well as intent. It is insufficient to examine documents and hold discussions, the team must observe what is going on, look into what is happening, assess the appropriateness and use of the resources and always bear in mind the need to help both teachers and students in any way possible to ensure that the students receive as good an education as possible. Last but not least, at the end of a visit the minimum result should be to have the institution concerned in as good a state as before. The object is constructive criticism.

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John Dubbey

Internal Evaluation Methods

For any academic program to be healthy and successful, it is essential that there be regular evaluation both of the initial course proposals. and the day-to-day implementation. This is true for all fields of study, but particularly for engineering, where the rate of change of requirements technological, sociological, and educational must be greater than in any other discipline.

To achieve this necessary evaluation, I am a great believer in the value of peer-group review. To have ideas made open to fellow experts, to users, to customers, to interested lay men and women, who will freely question and criticize those ideas, is a splendid way to clarify and deepen thinking, to instill the need to be continually learning and to work together more effectively with colleagues. Even if the questions turn out to be unsympathetic or even ignorant and incompetent, the fact that they are there to be answered, always improves the preparation and the subsequent performance.

I would like to discuss three types of internal evaluation: by the academic community itself, by the educational institution concerned, and by the wider world of industry and commerce. These remarks are drawn from my experiences as Dean of Engineering at a London polytechnic in the early 1980s and as Vice Chancellor of the University of Malawi in the late 1980s, where there was a substantial Engineering Faculty. Within these three concentric areas of interest broadly described as the department, the university or polytechnic, and the world outside, I will discuss what has been successfully practiced, and what additionally might be done.

Issues for Assessment

First, however, let us consider four fundamental problems of an engineering curriculum that evaluation groups need to be continually assessing:

- The technological provision.
- The general needs of an engineer.
- The theoretical basis.
- The traditional material to be omitted.

The technological provision is, of course, the essence of engineering, and the basic aim of any program must be to produce graduates who will be proficient in their particular technology, not for the 1970s and 1980s but for now and the next few years. In other subjects a more modest objective would be acceptable. But what makes engineering the most exciting and probably the most demanding of all disciplines is that only the absolutely contemporary is good enough. This greatly increases the demand because the technologies are changing and developing very rapidly. There will certainly be major changes during the three, four, or five years that the student is present, and these have to be taken on board. It raises a major question about the staff. Are the staff able to keep up with the changes? And if they are, do they have the equipment, the technician support, the administrative support they must have? Do the students have the opportunity to become familiar and proficient in these new technologies, and to think for themselves about how their subjects will progress?

The second area concerns the general needs of the engineer. This term does not refer to the general education of the engineer in subjects often covered by the headings of liberal studies or general studies, but to the necessary professional needs of engineering. The graduate engineer, proficient in his or her technology, will almost certainly encounter opportunities, even requirements, to lead and manage people, to write and speak effectively, to present cases and participate at board meetings, and generally to contribute toward the commercial success of the company. It is usually best for the company when engineers are able to do these things; otherwise non-technically based personnel such as lawyers and accountants must do them, and consequently command the better salaries. For the sake of the individual student, and as a requirement for attracting the best students into engineering as well as the more effective working of industry, it is necessary that this dimension be integrated into the curriculum and that the three levels of evaluation ensure that this is done.

Third there is the need for a theoretical basis. While technologies will change many times during the life of an engineer, the right sort of theoretical basis provided in the curriculum will enable the graduate to understand, keep pace with, and even anticipate the changes that will come. Theoretical bases also change, but not quite so rapidly as technologies, and it becomes a major skill of curriculum designers to formulate the most appropriate theoretical background. For example the electrical engineer of not so long ago was considered to be lacking without generous mathematical provision of Fourier Series, Laplace Transforms, and even Bessel Functions.

Today the engineer in the computer age should be more familiar with trees, graphs, lattices, and no doubt there are other aspects of pure mathematics like Systems Theory, Universal Algebra, General Topology which will become the necessary intellectual framework. The debate is continuous, and the mathematicians and physicists who may not have the same urgency with respect to the need for change must be brought into the curriculum and within range of the evaluators.

The fourth problem is the most difficult, requiring the finest of arts in curriculum design. The first three points describe new topics which must be continually fed into the curriculum machine—but what must be left out to make room for them? Almost any teacher can propose new material to add to a curriculum, but as the curriculum especially in engineering is almost invariably full to overflowing already and students are being saturated, for every new entry something has to go to make room for it.

This is an essential but inglorious task. Few would be prepared to relinquish easily what they have been teaching and maybe researching for years, and arguments will always be found about upsetting the balance of the curriculum, about depriving students of essential material, and agreement on these issues will not be easy. However, the task is vital and cannot be shirked. The overloaded curriculum will not achieve desirable objectives, and evaluating groups should be as interested in what is not being taught as in what is.

Three Levels of Evaluation

The basic issues of evaluation having been considered, the questions of implementation arise. The first level of evaluation is by those who are most concerned, namely the staff teaching the program and the students receiving it.

We had in London for many years a system of Program Boards concerned with the effective day-to-day running of the programs. A Board consisted of all staff teaching a particular program, and two or three students from each year, elected by their colleagues. It met at least once a term with formal agenda and minutes, the minutes to be subsequently available to all staff and students in the program.

The agenda could range over any topics relevant to the program. The student representatives, who without exception, took this task very seriously, made special efforts to consult with their colleagues before the meetings in order to bring any matter thought appropriate to this forum. Usually there would be an analysis of each teacher's performance, good or bad, with questions raised about the quality of the teaching, punctuality and commitment of the teacher, the frequency and difficulty of the assignments, the extent of coverage of the course and its relationship to the aims of the program together with any issues about classroom conditions, laboratory organization, technician support, and so forth. In turn the staff would raise issues about student commitment and responsiveness, and the program leader who usually chaired these meetings could make general announcements and discuss proposed improvements to the program. While all the issues discussed were of immediate concern, each one could be related ultimately to the four fundamentals described earlier.

These meetings proved to be ideal channels of communication between staff and students. For the students, they provided a formal mechanism to raise matters of immediate concern, the opportunity for mature consideration of their programs and the assurance that staff were seriously interested in attaining the highest standards of presentation to achieve the goals of the program. For the staff, the meetings offered a way to convey views to the student body on such matters as the purposes of particular course in relation to the whole program, their expectations from the students with suitable exhortations where necessary and most valuable feedback on teaching performance.

In most universities and polytechnic students have representation on committees at all levels but in our experience it was participation in these program boards which aroused the greatest interest and commitment. I have no doubt that the educational and professional quality of programs was greatly enhanced through this immediate form of evaluation.

The second level of evaluation is institutional. The first level assumes that the staff and students concerned have a major interest in the success of the program; the second assumes that the institution whether university or polytechnic is concerned for its reputation, built up largely through the strength of its programs. To this end, we devised in London, a means for institutional evaluation. In each faculty such as the Faculty of Engineering which ran about thirty different programs at degree, postgraduate, sub-degree, and technician levels, a scrutinising committee of academic staff drawn from all departments was established with the task of monitoring the programs accountable to it. The group met about six times a year, each time looking at about five of the current programs.

Each of the program boards was required to present three types of document for scrutiny, namely external examiners reports, minutes of program board meetings, and response to a questionnaire.

The aim was to discover as much information as possible about the program. The first two of these sources are fairly self-explanatory. The questionnaire was intended to derive facts and opinions not normally available from the other sources. The questionnaire is an adaptable device and in almost each year of operation we changed its structure to meet our interests and so ensure that all we wanted to know about a program could be available. An important principle was that the completed questionnaire should be first seen and approved by the program board, and the form included this assurance before it could be investigated. Below are set out not the actual questions asked but rather the areas of interest to the evaluation committee, since these can be adapted to different institutional needs:

How successful is the program in recruitment? How many applied for the program, how many were selected and how many actually arrived to begin the program? How was the selection procedure conducted, what were the criteria used, what sources of students were recruited, how well qualified were they, how many non-conventionally qualified were recruited, how many mature students, how many men/women?

What is the success rate of students on the program? How many passed each year of the program, how many failed, repeated or dropped out and why? It is often best to respond to this type of question with a flow diagram to indicate progression through the program. Is there any type of student who appears vulnerable?

External Examiners' Report. What are the comments of the program board in response to the external examiners' report?

Practical Experiences. If the program is sandwich based, how many students received industrial placement and were any difficulties experienced in securing these? Were the placements satisfactory for the program concerned? What supervision or assessment was provided by staff during the placements? Indicate the time spent in laboratories during the year. What industrial or professional experiences have students received other than sandwich placement?

Support for Program. How adequate is technician or secretarial support? Has new equipment been provided in the last year? What deficiencies in equipment or laboratory space can be identified?

Innovation. What innovations in teaching or learning methods, curriculum development, professional awareness, and so forth, were made in the last year?

Other Departments. Which other departments contributed to this program? What difficulties were experience and how well integrated into the major objectives were these contributions.

The great advantage of this method is that it can be adapted and extended to cover any aspect of the program which is thought to be of value; the seven examples indicated are by no means exclusive.

The report is then reviewed by the evaluation committee who would seek further information from the program board if necessary. The committee would then make an annual report to the faculty board on the health of all its programs.

The system could also be used in reverse. The faculty might be concerned from time to time about various issues such as the standard of mathematics, standard of written English, for example. These could then be included in the questionnaire so that the extent of any suspected problem can be more readily determined.

The third group of evaluators is the most important but the hardest to reach effectively. Clearly it is in the interests of students, staff and the institution that the program offered is as strong as it can be made. But the value of the program stands or falls by what the world of industry thinks about it. How are we to obtain the views of this most demanding constituency?

A basic method used successfully in Britain for twenty five years by the Council for National Academic Awards (CNAA) and now followed by most of the engineering institutions is for each program to receive an external review every five years. This normally means that a panel of academics and industrialists will visit the institution and discuss with the program designers (who will be expected to have proposed something new), many of the issues described already in this paper, and in addition will want to meet students, evaluate the facilities, investigate the institutional support and look for evidence of successful interaction with industry.

This interaction can take many forms but the panel will be seeking evidence of confidence placed in the program by the appropriate industries. Examples are the existence of consultative/liaison committees, success in placement and employment of graduates, short courses, services and consultancies performed by staff, equipment and specialist visiting lecturers provided by industry. These panel visits are always a major highlight in the development of a program, especially when the visitors have the authority to lay down conditions to be satisfied for future running of the program, or even the authority to withdraw approval.

It is not always possible to have the benefit of a scrutiny by such a range of expertise, although on an international scale this might be a possibility, but in Malawi we devised our own method, and in fact went much further in the search for objective evaluation.

Evaluation by Research Study

We attempted a research study in 1988 to locate all our graduates in all disciplines including engineering in order to discover where they were employed, how their careers had progressed, and most important to us, what they felt about the value of their university education in relation to their personal and professional development. Over a thousand detailed responses to our questionnaires were received.

Not only did we seek this information from our graduates, but we also made an effort to locate employers and seek their opinions on the abilities and qualities of our graduates. Each section of the university was encouraged to put both general questions and others specifically related to their course of study. In the case of the engineers, we invited both graduates and employers to supply their own comments in addition to replying to the questionnaire. These comments came in frankly and were most helpful. Some suggestions advised us to do things which we were in fact already doing, and others provided new ideas about the type of teaching, practical, and professional preparation which were needed to improve the programs.

One factor very strongly expressed by both graduates and employers was the acute need for management preparation. The graduates were technically satisfactory for employment, although better on theoretical than practical performance, but lacked this vital professional quality. When asked to suggest what postgraduate short courses we might offer for engineers, while some technical development was suggested, management courses prevailed as the major need. Other deficiencies identified were in computing and in the use made of industrial placements.

The exercise is capable of improvement, and from experience a more appropriate and penetrating set of questions may be designed. The major point, however, is that if we are truly concerned about the value of our programs, then some effort has to be made to seek this third type of evaluation.

I have defined three constituencies of interest. Provided we agree these all need to be satisfied, the methods used can vary.

The task is considerable, but the combined effort of a group of staff determined to improve standards, in the correct sense of that much ill-used word, can succeed. In the educational world we have all experienced the deep satisfaction of effective teaching. To work with a team to ensure that a particular program really fulfills its purpose is a quite comparable blessing.

Part II

Assessment of Engineering in Developing Countries

K. Koso-Thomas

Engineering Education for the Labor Market in Africa

Most of the African region is now burdened with disabling economic stagnation. The situation has led to an alarming decline of established manufacturing industries, particularly those dependent on imported raw materials and spare parts. Restrictions on long-term lending by financial institutions are stifling expansion of small scale industries, and production levels of certain ore and mineral extracting industries have dropped as world demand for them shrinks. Understandably, however, there has been an increase of activities in the informal engineering sector, particularly in the craft areas of metal work and woodwork, improvement in the volume of certain classes of building construction contracts, and expansion of plant and vehicle maintenance services, including conversions, adaptations, and manufacture of some kinds of spare parts.

While there are limited opportunities for employment within this general prevailing condition, there is a variability of opportunities covering much of the spectrum of engineering practice, from the relatively sophisticated, that is, somewhere near the top end, to the unpretentious grass roots technology, somewhere near the lower end of the spectrum. Of course, there are differences in country situations. Some countries are at a relatively more advanced stage of technological development than others, and so may have greater opportunities for engineering practice at the upper end of the technology spectrum than at the lower end. Furthermore, in those countries which have successfully established strong economies and wish to modernize their technologies, there may also be more scope for top end engineering practice than in a poor country struggling to maintain primitive systems.

Two questions therefore arise: should engineering education for Africa be standardized, and what level of theoretical and practical knowledge is required for professional practice in Africa? The answers to these questions are vital for the proper channelling of scarce resources into the engineering education system, for reducing unnecessary wastage, and producing highly valued and easily usable engineering manpower for the labor market.

Standardization and Quality of Education

Considering the differences in economic fortunes and in the state of engineering practice in countries of the region, it would seem reasonable to assume that standardization of the curriculum would be undesirable. For it could be argued that content of courses must be related to knowledge levels demanded by employers as well as to the socio-cultural complexion of the working environment. Even so, there must be for every discipline, a core of knowledge around which various components influenced by contextual factors could be fitted. Thus, there seems to be justification for developing a standard core curriculum which should serve the needs of every country in the region. Quite apart from this, the introduction of some degree of standardization will facilitate the pooling of manpower resources for regional development, the promotion of increased mobility of skilled personnel within the region and perhaps, to a much greater extent, the achievement of a more economic and efficient education through the sharing of training facilities in regional centers of excellence.

Determining the level of theoretical and practical knowledge at which engineering education should be pitched has always been a controversial issue. One view on the issue is that, while education should be relevant, one cannot Africanize engineering. The classical treatises of the applied sciences must be learnt before prospective engineers are introduced to techniques of application (*Koso-Thomas, 1970*). This view is in line with the earlier traditional separation of training methodologies for the acquisition of theoretical knowledge from those for the acquisition of practical skills.

Other views have tended to follow the line that African engineering education should concentrate on aspects which are readily applicable within African communities (*Shojobi, Kwakye, Brown, 1970*). It is difficult to accept this position without the caveat that attention should be given to the study of carefully chosen modules of advanced physical principles which will lay the foundation for future understanding and participation in new developments.

No matter how valid this view may be, there are in place in some countries, certain systems which would require specialist manpower for their operation and maintenance, or for their adaptation to local conditions. Thus, at some stage or other of his education, it may be important to provide the prospective engineer with an understanding of the type, scale and complexity of selected developments taking place in technology. Introduction should also be given to system efficiency studies, adaptation techniques and innovations required, or being undertaken in indigenous systems in his own country.

These contrasting views in engineering education indicate that the definition of appropriate standards for the education of the engineer in Africa can be a delicate matter. In an era in which educational standards are being revised to match the transformation taking place in industry and society in most parts of the world through the introduction of new technologies, it will not be prudent to give the impression that Africa should be relegated to training engineers for an age that has passed. At the same time, it will be unrealistic and counterproductive to concentrate on producing engineers with a mastery of the most advanced subjects on the frontiers of knowledge, when most of them cannot be absorbed by the labor market. Besides, aspiring to too high a standard of education in certain African situations might impose unreasonable financial pressures on educational institutions, and cause neglect of other more urgent demands of the overall educational system.

Objectives of Engineering Education for Current Needs

The state of the labor market for engineers suggests that the demand is for skills in operating systems, especially in the electrical, electronic and mechanical fields. A few of these systems require some highly advanced and specialized knowledge. Many others are still of limited complexity. There appears to be demand also for:

- Some design and manufacturing skills for the production of certain classes of mechanical devices.
- A wide range of design and construction skills for civil and public works engineering projects.
- Engineers with the right practical aptitude, willing to "do it" when the technician will not or cannot.
- The engineer who is properly sensitized to the socio-cultural problems and perspectives of the environment in which he is expected to work.
- An engineer with the communication skills to facilitate work among people of basic educational and diverse linguistic backgrounds.
- An engineer who has the resourcefulness, drive, and initiative to operate under abnormal productive conditions including frequent shortages of raw material, unavailability of conventional equipment, and unreliable power supply.

At the top end of industrial activities in some countries, the need exists to have personnel with the requisite specialized knowledge and training to help industry expand and be more productive. This makes it important to provide appropriate post-graduate education which incorporates investigative research identified by industry and carried out with their collaboration. There are also limited openings in research establishments set up by research councils and other government and private bodies in a number of countries, and some openings certainly in teaching and research at universities, which are difficult to fill at this time and for which training is necessary.

However, some selectivity is important, and not all fields of scholastic interest should be pursued. Focus should be given to specialized branches of knowledge demanded by the local situation, or directly related to national development goals, such as those in agricultural engineering devoted to the study of post-harvest losses, irrigation, adaptive mechanization, and so forth; those in civil engineering relating to problem soils in highway construction, water resources exploration and exploitation, public health; and in electrical and mechanical engineering, knowledge areas relating to power generation, metallurgy, and computer software development and management.

Two types of postgraduates are therefore clearly needed. The first type is the operational specialist whose role should be to provide better and more expert application of existing knowledge in fields relevant to the employer's needs. The second is the innovative specialist, whose role is to increase the rate of generation of new ideas, and to supply the techniques, materials, and devices needed by the operational specialist (*Walker, 1966*).

Undergraduate Education

Any set of objectives of engineering education at the undergraduate level which will produce an engineer who would be employable as well as retainable within the African labor market should include:

- The provision of relevant technical and managerial skills, particularly for small industries.
- The encouragement of entrepreneurship.
- The imparting of basic knowledge of local scientific and technological capacities and possibilities.
- The development of an awareness of the

socio-cultural and environmental problems of selected areas of the region.

- The provision of adequate communication skills.
- The provision of adequate practical orientation and the development of an attitude to work which produces desirable results.
- The development of skills for problem identification and solution.

Suggested Undergraduate Course Pattern

Courses of study should therefore include:

- General study of basic physical principles.
- In-depth study of one major engineering subject, highlighting processes of innovation and the essential linkages between research, innovation and production.
- In-depth study of the overall behavior of engineering systems, such as electrical power networks, communications networks. water supply and sewerage.
- Familiarization with systems available in the locality, including their installation and management.
- Some basic technician and craft training.
- Study of time principles of engineering design with relevant applications to solve locally identified problems, including examples and assignments in adaptation.
- Management studies, including personnel management, industrial relations, business methods and basic accounting procedures.
- General studies in maintenance engineering including relevant applications.
- Studies of indigenous materials, systems and processes.
- Study of the development of science and technology in Africa.
- Study of the social and cultural implications of the application of traditional and foreign engineering systems and processes.
- Training in communication skills, including technical writing.
- Some on-the-job pre-graduation training.

These various courses need to be so organized within a structured program that a set of core courses will emerge with options properly arranged in groups or modules into which they naturally belong.

Postgraduate Education

The objectives of postgraduate education should be, for the foreseeable future:

- The mastery of knowledge in selected subject areas.
- The development of investigative skills.
- The provision of stimulus for creativity.
- The creation of an awareness of the integration of engineering disciplines.
- The development of an appreciation of cultural and aesthetic values.

Postgraduate courses should be given, as is now common in most African higher educational institutions, by formal tuition in selected specialized subjects, or by supervision of research in a narrow field of a chosen discipline, or a combination of both. For the operational specialist, formal tuition is necessary. However, such specialists could also benefit from a properly adjusted combination program. In the training of the innovative specialist, more weight should be given to research, the acquisition of a scientific attitude, and exposure to a wide range of experience. The course pattern suggested below gives only an idea of a possible array of courses. Some flexibility should be exercised, particularly when choosing courses for the operational specialist. In every case, however, the overriding consideration in developing postgraduate courses should be relevance and efficiency, so as to gain the support and patronage necessary from all categories of employers for the survival and growth of such courses.

Suggested Postgraduate Course Pattern

- In-depth study of specific subjects agreed with local industries, the ministries of education, industry, agriculture and development and research organizations with the potential for employing postgraduates.
- Study of instrument design and instrumentation techniques.
- Study of research methodology, including data collection or retrieval procedures and analysis methods.
- Study of the history of science and technology.
- Programmed participation at interdisciplinary seminars.

Institutional Structures and Arrangements

The drawing up of useful curricula and the arrangement of courses for engineering students at all levels should take account of the students' background, including familiarity or otherwise with science and technological devices, previous social and cultural environment, and previous education. Attention should also be given to content spacing, maximum contact hours appropriate for the teaching methodology to be adopted, and to any limitations to teaching and learning effectiveness imposed by shortcomings of the support facilities, including current literature, laboratory equipment, and practical examples. It is also important to ensure that institutional arrangements for providing the required education are compatible with the objectives of that education.

Instructional Strategy

Details of strategies which have been developed for introducing innovation into the training of technological manpower for Africa (*Koso-Thomas, 1985*), have been linked to possible models of development for the region. There is no doubt that instructional and institutional systems and arrangements have to be compatible with national development philosophies. Such philosophies will influence the interpretation of the basic objectives outlined. They will also guide the choice of course options even if core courses are retained intact for all models.

Consider for example, the development model which accepts the initial adoption of technologies developed outside the region as the basis for promoting economic and social change and progress. In this case, objectives such as providing relevant technical and managerial skills, development of aesthetic and other values, stimulation of creativity and appreciation of indigenous systems and processes, will have been met by selecting options or modules which develop competence in the identification of alternative sources and selection of technology types, appraisal, procurement and contract negotiations. The development of science and technology capacity will similarly be said to have been achieved through the introduction of courses which emphasize operational techniques, maintenance and manufacture. Since, however, the strategy of the model is to promote change and progress through the utilization of foreign technology, it will also be expected that these courses will develop the stimulation necessary to question basic flaws in design to be able to introduce conversions and modifications. An alternative model which rejects the introduction of new foreign technology and aims at protecting and enhancing existing traditional technologies will foster the strengthening of traditional skills and the upgrading of indigenous systems by stressing courses involving the development of science and technology in Africa, indigenous materials systems and processes, innovation, craft training, equipment and tool design, and rural studies.

Institutional Strategy

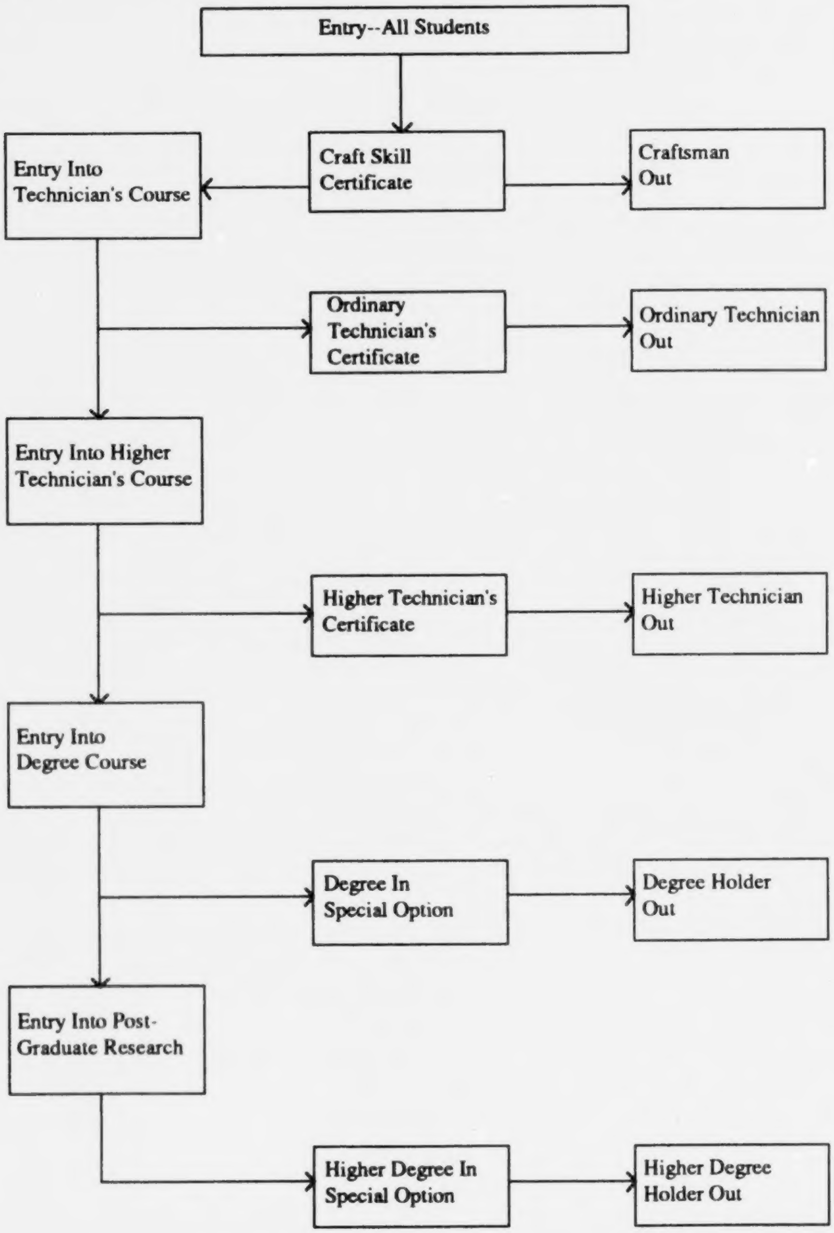
It has been argued that engineers could be more effectively trained for the African labor market if the adaptability and versatility called for by employers were reflected in the structure of the institutions in which their education and training are carried out (*Koso-Thomas, 1985*). It is believed that in addition to existing university engineering faculties and higher technical institutes at which the bulk of engineers are now educated, a number of specialized colleges for engineering and vocational education should be established, to provide the humility, modesty, versatility, and practical orientation desired in an engineer in Africa. Entry to these colleges should be at all levels, starting from the minimum entry qualification normally accepted for craft training. A proposed structure is illustrated in Figure 6.1.

Each college should be associated with an engineering concern which should undertake to reserve training positions in their organization for students on mandatory programmed attachment. Each attachment should be of reasonable length and students should be regularly evaluated and given grades which should form part of their academic assessment throughout their course. Degree registered students would be able to move faster through the craft and technician's training streams of the integrated program than others. Students with weak entry qualifications would have the opportunity to move through the program at their own pace and to the limit of their intellect. Backward linkages with primary and secondary schools should be established for the new colleges as well as for existing engineering colleges and faculties, so as to influence the sources from which students come, and create an awareness at school of the importance of engineers in the development of nations.

Conclusion

Education for engineers should give them some universality, and more particularly, the adaptability to practice in both the modern and traditional sectors of life. It should make them readily marketable in the labor environment and, above all, it should help them contribute to the general effort to bring inspiration and hope to the many now so desperate for change and prosperity.

Figure 6.1: Proposed Structure for a Typical Subsector Specialty


Entry--All Students
Entry Into Technician's Course
Craft Skill Certificate
Craftsman Out
Ordinary Technician's Certificate
Ordinary Technician Out
Entry Into Higher Technician's Course
Higher Technician's Certificate
Higher Technician Out
Entry Into Degree Course
Degree In Special Option
Degree Holder Out
Entry Into Post-Graduate Research
Higher Degree In Special Option
Higher Degree Holder Out

Source: Report to the United Nations Economic Commission for Africa and the United Nations Industrial Development Organization on Innovative Ways of Developing and Utilizing Industrial and Technological Manpower for the Implementation of the Program for the Industrial Development Decade for Africa.

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Benjamin A. Ntim

Methodology for Designing Engineering Curricula in a Developing Country

The task of drawing up an appropriate curriculum in engineering education for a developing country is difficult for a number of reasons.

- Due to the phenomenal growth in scientific and technological development, course contents tend to be overloaded.
- Since the technological background of those selecting engineering courses is low, much time is needed for teaching engineering foundation courses.
- Because teaching staff have little industrial experience, the courses as taught may not have the necessary national relevance.
- Despite improvements in educational technology such as the use of computers and audiovisual techniques, these countries lack the facilities for students to benefit from them.
- Finally, after the classroom, the education and training of an engineer should carry on into industry. However, because there is usually a shortage of engineers in developing countries, freshly graduated engineers often take on professional responsibilities of enormous importance much earlier than their counterparts in industrial countries. This situation should be reflected in the curriculum which must be planned for a finite period of between three and five years.

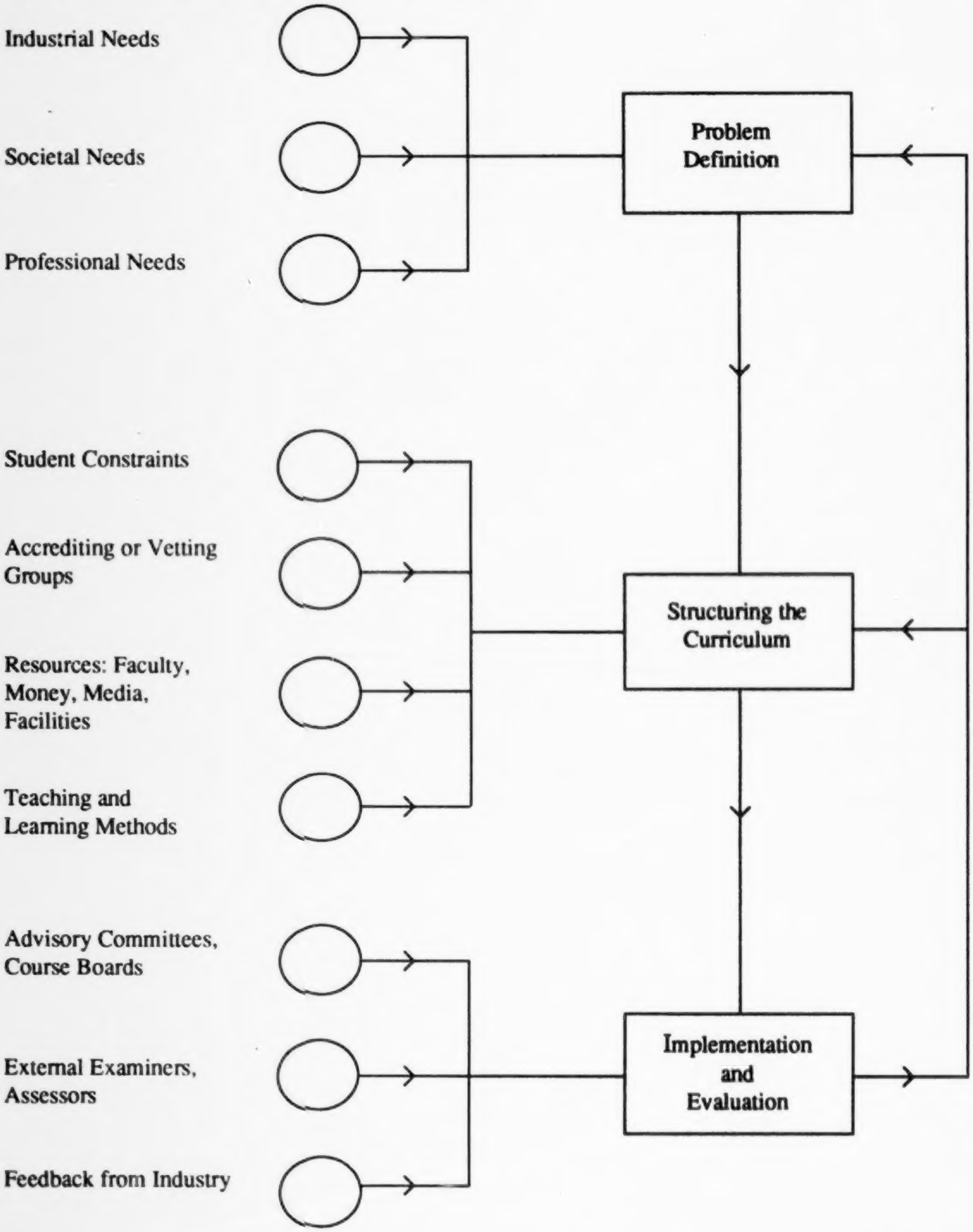
These factors make the systematic design, implementation, and assessment of engineering curriculum in developing countries rather complex and demanding. In this discussion an attempt will be made to define and analyze various factors that need to be considered in drawing up a methodology for assessing the engineering curriculum in a developing country.

Elements of Curriculum Design

The elements of engineering curriculum design are presently well documented thanks to a number of international studies that were initiated by UNESCO in the 1970s (Ref. 1, 2, 3, 4). According to these studies there are three main stages that can be identified for drawing up a universal methodology for the design of the engineering curriculum. These are, as illustrated in Figure 7.1, problem definition, structuring the curriculum, and implementation and evaluation of the resulting curriculum.

The diagram indicates that, to arrive at a properly designed engineering curriculum, it is necessary to have a built-in procedure for continued assessment of the original sets of goals and objectives. In other words, a good engineering curriculum must be designed in the context of the socioeconomic and technological needs of a given society as demonstrated by the current level and aspirations of the society's industrial

Figure 7.1: The Design of Engineering Curricula


Industrial Needs
Societal Needs
Professional Needs
Problem Definition
Student Constraints
Accrediting or Vetting Groups
Resources: Faculty, Money, Media, Facilities
Teaching and Learning Methods
Structuring the Curriculum
Advisory Committees, Course Boards
External Examiners, Assessors
Feedback from Industry
Implementation and Evaluation

development. From an objective analysis of the societal needs, the goals and the desired objectives of the engineering curriculum may be derived as well as defined. It is only then that the structuring of the curriculum in terms of the numbers of students, the scope and types of engineering disciplines, human and material resources, and the mode for delivering the contents of the curriculum, can proceed. After the design of the curriculum, the implementation will be affected by changing conditions, so it will be necessary to devise mechanisms for the continual revision of the curriculum in a systematic and logical manner to keep it in line with the true needs of the society.

The brief methodology described above may be adapted and adopted as a model by any society or nation for designing an engineering curriculum. However, too many differences exist among nations and even within a single nation to permit the insistence of a rigid formula for universal application. Extraneous factors will therefore influence the final detailed procedure to be adopted in a given situation. Some of these factors were mentioned earlier. The questions of interest for a developing country are

- What are the current assessment methods and to what extent should external methods, such as those of the American Accreditation Board for Engineering and Technology (ABET) or those of the British Institution of Engineers, be recommended for these countries? (Ref.5).
- How should the different components of the engineering curriculum, as specified in the three stages described in Figure 7.1, be assessed?
- What relative importance should be assigned to each of the components?
- What weight should be given to regional and international considerations as opposed to national ones in the design and assessment of engineering curriculum?

Limited examples from some developing countries illustrate possible guidelines that may be followed.

Current Assessment Methods in Developing Countries

Most engineering programs in developing countries have no formal mechanisms for the conduct of regular external assessments. It is necessary, however, to distinguish between the different objectives of external assessments and self-assessments. Most developing countries do carry out the latter type of assessment.

Self-assessment is generally conducted at the faculty or departmental level to determine the improvements in educational and training methods that could be carried out within the prevailing financial and resource constraints. Such an assessment undertaken in cooperation with the administration can play an important role in improving teaching, strengthening the unit's management, accelerating educational reform by stimulating staff enthusiasm, and enhancing the educational quality. This exercise can also provide useful inputs to any subsequent external assessment. Its usefulness can further be extended by including the participation of representatives of government, industries, and professional institutions. Most developing countries in Africa, the Arab states, and to a lesser extent Asia carry out this type of assessment; however, the exercise is ad hoc rather than institutional.

Occasionally, engineering departments and faculties in these countries are subjected to external assessments, but with the purpose of determining new areas for developmental assistance either from bilateral or international sources. It is worth nothing that most of the engineering institutions in these countries have been at one time or another been tied to educational systems in industrialized countries. This fact has helped to maintain high academic standards although in some cases it has hindered the cause of social relevance.

In the densely populated developing countries with numerous engineering institutions, such as India, China, and Mexico, some form of national assessment in engineering education and training exists, but, hitherto, the objective has been to categorize the institutions into different levels of excellence (Ref. 9). In China since 1985 an institutional framework for assessing higher educational institutions, including those dealing with engineering, has been introduced (Ref. 8). The methodology of approach has been rigorous in the assessment of human and material resources. However, due to the traditional separation between educational institutions and industry in that country much remains to be done to integrate industrial components into the assessment methodology. Further, uniform quantitative criteria concerning numbers and types of staff are in the process of being formulated.

Developing countries are generally in a rudimentary stage of assessment of their engineering education and training. Systematic development of suitable methodologies is needed to help these countries adapt their training facilities to suit their national requirements.

Assessment of the Components of the Engineering Curriculum

One school of thought supports the idea that the assessment of the engineering curriculum must be centered on the product of the engineering educational system, namely on the performance of the freshly graduated and professionally qualified practicing engineer. This argument may be valid but it fails to provide a complete picture of the role of an engineer in a changing modern environment. An effective engineer is expected to command a good grasp of scientific knowledge, have specific technical skills, be capable of managing and, as a member of a team, implementing multi-disciplinary projects, including the maintenance of economic viability. The engineer must also have the ability to communicate ideas to superiors, colleagues, and subordinates, and at the same time take responsibility for the effects of actions on society as well as on the environment. Shortly after entering industry, it is not possible for most graduates to demonstrate all these capabilities in all of the differing engineering situations they will encounter. For this reason, there is the need to assess the three different stages of the curriculum design.

The first component of the curriculum system-problem definition—sets out goals and objectives, and requires a thorough knowledge and analysis of the country's societal, industrial and professional needs. Such an analysis will have an enormous influence on the types, of technical manpower which the curriculum should address. Indeed, from time to time this problem-definition statement will have to be revised to respond to the changing technological scene. Furthermore, it is important that all interested parties from government, professional and educational institutions, and industry play a role in formulating the goals and objectives.

The nature of the issues to be raised at the problem-definition stage are illustrated by five objectives set for the education and training of engineers in a typical small developing country in Africa that recently undertook a review exercise (Ref. 7).

- To impart requisite theoretical knowledge in engineering science to an acceptable standard and to balance it with appropriate practical training courses which bring out clearly local peculiarities and constraints in engineering activity in the country.

- To expose the student to properly conceived and organized practical training as early as appropriate during the program of study.
- To introduce the student sufficiently to the engineering environment in the local industry, if possible, before the student enters the university.
- To design the degree program in such a way that most of the engineering fundamentals should be covered mid-way through the program so that the student can specialize in the final years and have time to execute engineering projects of local relevance.
- To use teaching methods that aim at developing creativity and an analytical mind, that show the approach to and the techniques for solving new problems and that emphasize the importance of decision-making in engineering practice.

The above review exercise was carried out in Ghana, a relatively small developing country with a population of about 14 million, only one school of engineering, and a total stock of engineering manpower of about 7,000 representing about 0.5 percent of the work force, as compared with 1 percent for Australia and 2 percent for the United States for example (Ref. 6).

The review also indicated that about 80 percent of the engineers are engaged in the operation and maintenance of the various manufacturing enterprises, utilities, mines, and construction companies, over 19 percent in consultancy services, and less than 1 percent in research and development. Thus, for a country like Ghana and nearly all other African countries with a similar engineering work force profile, such as Cameroon, Kenya, Sierra Leone, Tanzania, and Zambia, the course content should emphasize relevance to the specified objectives.

From such criteria the relative time can be allocated for the different components of the engineering course content comprising mathematics, basic sciences, engineering sciences and laboratory work, engineering design, project design and management, social sciences, and industrial visits and training. The same criteria will also determine which subjects in any given engineering discipline should be made compulsory and which offered as elective subjects. However, with the rapidly changing technological scene, it is necessary to systematically revise the curriculum.

For small developing countries with limited industrial infrastructure, little or no capacity for undertaking frontier research in engineering, and lacking in adequate numbers of technological manpower, the need to emphasize relevance to current industrial practices in the design and assessment of a curriculum may be justified. In contrast, relatively large developing countries such as Brazil, China, India, and Mexico, which are more industrialized than the small developing countries, but less sophisticated industrially than the developed countries, are more likely to emphasize fundamental principles. This trend is currently the case in China (Ref. 5). Moreover, in these countries it is practically impossible, due to large student numbers, to arrange industrial training attachments during the educational program, therefore necessitating initial industrial training after graduation but before professional qualification.

The third component of the curriculum design stage becomes exceedingly important in countries where professional qualification is awarded following industrial practical training of a specified duration after graduation. In this case, it is not the length of the post-graduation training that matters but the way it is structured.

Following the above comments on the third and first components of the curriculum design as set out in Figure 7.1, the emphasis for assessing engineering education must necessarily revolve around the second component. Thus, there is the need to devise appropriate methodology for rigorously assessing the resources, course syllabi, accrediting or vetting groups, teaching methods and student constraints and background of the engineering institution concerned.

Since these components are discussed in detail elsewhere in this book, it is necessary to add only that the assessment exercise has to be undertaken by an external body working in cooperation with the members of the institutions. This assessment is best carried out by a national accreditation board if the institution is one of several in the country. However, if there is only one engineering institution in the country, an effective assessment can be achieved only through collaboration with regional or international engineering bodies.

Regional and International Considerations

In matters of technology transfer no country can survive by isolating itself from all others. Because effective technology transfer is greatly dependent upon technical manpower, programs for the education and training of this type of manpower in one nation must relate to what is happening elsewhere. Luckily in engineering education there is much interaction between engineering institutions in the industrialized countries and developing countries on the one hand, and between such institutions at the regional level on the other. The former interaction derives from historical developments and the latter from the need to promote technical cooperation among developing countries, a process which is actively coordinated and supported by international agencies.

Especially since the 1960s there has been the tendency to encourage the globalization of engineering education. Thousands of students from developing countries have undertaken both undergraduate and postgraduate studies in Europe and the United States. Large numbers of these students presently occupy important teaching and administrative positions in the engineering schools in developing countries. Before and during the same period, and under the aegis of various bilateral and international arrangements, engineering staff from the developed countries also assisted in setting up engineering institutions in the developing countries and training the local staff. These types of exchanges and regional international seminars and workshops have in many instances encouraged twinning arrangements between engineering institutions from the north and south. Twinning arrangements are a useful mechanism for the harmonization of curricula between participating institutions.

Satisfying the qualification requirements for postgraduate work in the industrialized countries has been the biggest consideration in aligning the curricula of engineering institutions in the developing countries to those in the industrialized countries. This need has clearly stimulated various curricula reforms in the former countries, certainly at the undergraduate level.

Finally, there is much movement of technical manpower at the regional level in contrast to movement at the international level which led to massive brain drain in the developing countries in the 1970s and 1980s. A country like Jordan with a total of about 18,000 engineers has roughly half of this total working in the neighboring countries. A quarter of Ghana's technical manpower is spread around Africa and elsewhere. Indeed, formal sub-regional and regional groupings are being formulated in the Arab countries and also in Africa to encourage free movement of personnel. Serious account needs to be taken of these trends in the design and assessment of engineering curricula.

Conclusion

A systematic methodology for designing an engineering curriculum has been analyzed with particular reference to developing countries. This methodology comprises three components, namely problem definition, curriculum structuring, and implementation followed by evaluation. It has been shown that the methodology provides all the essential elements for effectively assessing engineering education and training in developing countries.

At present not much systematic external assessment is undertaken in developing countries. Ad hoc self-assessment exercises are, however, carried out by most engineering institutions and are helpful in bringing about reforms in teaching methods. The exercises also could encourage the interaction of engineering education with industry if representatives of the latter and other related institutions are invited to participate in the assessment.

The little external assessment that goes on in developing countries has only recently been initiated. However, this situation does not necessarily result in poor academic standards because most engineering institutions in developing countries have maintained some ties with similar institutions in the developed countries which has helped to ensure some academic correspondence. If anything is lacking it is relevance to prevailing industrial conditions, which in turn may be attributed to the insufficient knowledge of or links to the local industrial system by the staff of engineering institutions. Any contemplated assistance to the development of assessment methods should address this problem.

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Part III

A Practical Guide for Assessors in Developing Countries

Manuel Zymelman

Assessing Engineering Schools

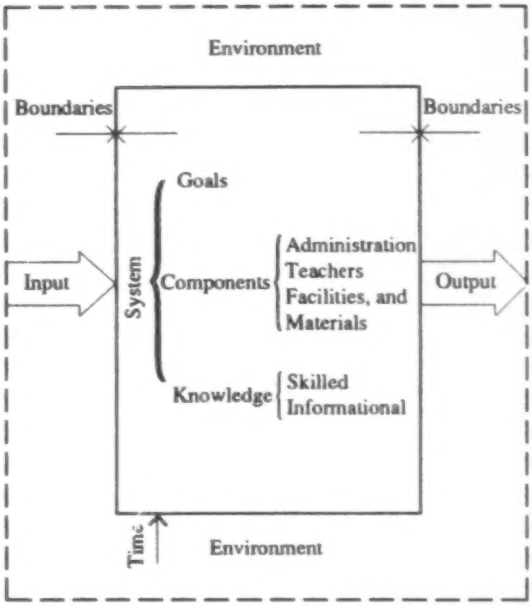
Introduction

The economic development of a country depends on its ability to incorporate technological progress as an ongoing process. Historically, the engineering profession has been the fulcrum for technological adaption and innovation. The continuous improvement of engineering education is therefore necessary for creating the human resource base for technological development.

Improvement of engineering education has different definitions. The teaching process can be improved without changing the content of what is being taught, or the content can be changed without changing the teaching process, or both. From an economic point of view, given prices of inputs and budgets, improvement of engineering education can be considered in terms of internal and external efficiency—the choice of processes that maximize the economic value of output within a given budget or minimize the cost of producing a given output.

In my opinion, the process of engineering education should be looked at from a systems point of view, a system being a unit formed by many diverse parts that are subject to a common plan, or that serve a common purpose. A system takes an input or inputs which it transforms into an output, or outputs. The engineering education system is composed of faculty, administrators, buildings, and equipment. These parts are combined and directed by economic and social rules. The common purpose that unites these parts is the education and training of students in order to produce engineers proficient in the profession and useful to the economy. The student (input) enters the system, and later graduates or drops out (output) (Figure 8.1). Systems are affected by boundaries, environment, and knowledge.

Figure 8.1: The Engineering Education System



Boundaries affect the ability to make efficient decisions. For example, if the number of students admitted to the various engineering specialties is decided upon by an authority outside the system, and in spite of a good education many graduates don't find employment, the institution cannot be held accountable for the inefficient decision-making in the choice of output. If the boundaries of the system expand to include the decision-making process on the type of graduate and the engineering school still produces a large number of graduates who don't find employment, then there is an inefficiency for which the school is responsible.

Environment is the sum of external conditions and influences that affect the functioning of the system. The results of a transformation process, operating on given inputs in a particular system, vary as the environment changes. A school operating in a peaceful environment produces a higher output than the same school operating in a violent one. An environment hostile to learning will adversely affect the output of the system. An authoritative and intimidating environment will inhibit innovations.

A process that goes on in a system where there is human activity depends on *knowledge*. The reason for organizing the system, the way the system operates to transform a given input into desired outputs, and the way it adapts to changing conditions—all these depend on the knowledge available to the system's members. When the knowledge available to the members of the system is inadequate, inefficiencies will certainly result.

Improvement of engineering education from a system's point of view consists therefore in improving efficiency of the engineering education system by reducing inefficiency.

There are two types of inefficiency: inefficiency of operations, and inefficiency of decision-making.

Inefficiency of operations occurs when members of the system do not contribute their best potential to the transformation process. In two engineering schools with the same type of professors, number of students, materials, and so forth, if the graduates of one school are better than those of the other, the school with the poorer graduate is more inefficient. The basic question is: if systems are similar, why do results differ? Systems can be similar and yet not exactly the same. Some of the system's members may be different and these differences are hard to account for. There are a number of intangible elements—attitudes, motivation, cultural heritage—as well as tangible aspects, such as incentives for students and faculty, which lead to differences in performance.

Inefficiency of decision-making occurs when choices concerning combination of inputs—professors, laboratories and equipment, materials—and their allocation—are not based on an *a priori* criteria of efficiency. For example, the allocation of resources to train a specialty of engineers for which there is no demand is an inefficient economic decision. The same can be said when misallocation of clerical staff compels faculty to spend large amounts of time on clerical tasks rather than in teaching or research. Sometimes even the choice of an *a priori* criteria can be judged to be inefficient from an economic viewpoint. If the *a priori* criteria is political, such as the allocation of resources to further a political goal, the results can be an increase of economic inefficiency. For example, appointment of professors on the basis of political or tribal affiliation will probably produce poorer or more expensive graduates.

How can we reduce these two types of inefficiency? By changing the boundaries of the process, by changing the environment, and by increasing knowledge.

Changing the boundaries can help alleviate inefficiencies of choice. It may mean internalizing what is now an external decision. For example, the decision on the number and quality students to be admitted if now taken by the ministry on a political basis, could be transferred to the faculty of the engineering school where, presumably, an economic criteria is more prevalent. Conversely, consolidating smaller independent processes into a central one may also help efficiency if economies of scale are realized.

Changing the environment. The environment greatly affects the inefficiency of operations. One way to reduce this kind of inefficiency is to affect the incentives of the members of the process. The value that society places on the quality of teaching and of graduates, the professors' freedom to innovate, the attitude of employers toward quality, the way the whole economic and social system outside the process operates, all of these affect operational efficiency. If these are changed, the efficiency of the process can be changed.

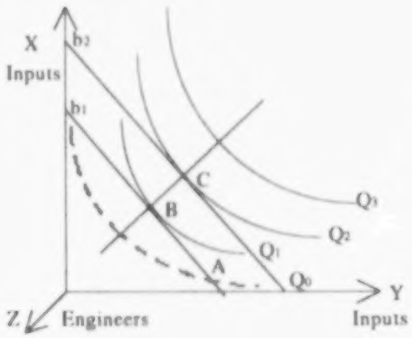
Increasing knowledge. Knowledge can be classified into two major types: skilled knowledge, or the way to do things, and informational knowledge, or having the facts and the understanding of them necessary to make the right decisions.

Skilled knowledge is acquired through education and experience. The way things are done at present is learned. At a higher level, knowledge leads to solving new problems by creating new ways to do things. This knowledge usually results from intuition which leads to research and experimentation. For a faculty member in an engineering school, operational knowledge is the knowledge needed to teach effectively. This is a knowledge that can be acquired in academia and from years of experience working and solving real engineering problems.

On the other hand, informational knowledge is especially useful for administrators and managers. For example, to determine the optimal number of students, or forecast the financial requirements of a program, it is important to have the appropriate data. (The way the data is analyzed is, however, skilled knowledge.)

In the analysis presented above, I have proposed a general approach for improving engineering education (which could be a general approach to improve any type of education) through increased efficiency, but no budget constraint was mentioned. Once a budget constraint is introduced, there is a limit to the level of quality of product (engineer) that can be achieved if a given number of engineers are to be produced. If that level of quality is below a minimum acceptable level, there is no other recourse than to increase the budget or reduce the output.
Using the analogy of an economic production function (Figure 8.2) to produce Z number of engineers with an inefficient system with a budget "b_1" only A or Q_0 quality can be achieved.

Figure 8.2: Production Function



By introducing efficiency measures we can move up to point B. However, if Q_1 is below the minimum acceptable quality level needed to perform successfully as an engineer (Q_2), it may require an increase of budgetary resources from "b_1" to "b_2" to reach C on the acceptable Q_2. In summary, to improve engineering education it will be necessary to:

- ascertain the need for training "Z" engineers in accordance with economic demand, and the cost effectiveness of training at home or abroad;
- determine the present situation of the institution (point A) and its efficiency (level Q_o);
- determine what measures are required to overcome existing inefficiencies (improving knowledge and changing boundaries, environment) in order to move from point A to point B on Q_1;
- define a minimum level of quality compatible with the requirements of an engineering occupation (Q_2); and
- determine the budget (b_2) needed to provide Q_2.

This study deals with the first and second steps: quantitative and qualitative assessment of engineering needs, and efficiency assessment of the training institutions.

Assessment of Qualitative and Quantitative Training Needs

Qualitative Demand

While the quantitative analysis provides the scope for an engineering institution, it is the engineers' job description that determines the type of curricula, teachers, materials, and equipment required for transforming a given type of secondary school graduate into an entry level engineer.

The Content of the Engineering Occupation

Successful performance in an occupation, say an engineering job, requires a composite of skills (manual, intellectual, cognitive, social), and experience. However, this combination of skills is not immutable because the functions that an engineer has to perform vary in relation to four different factors:

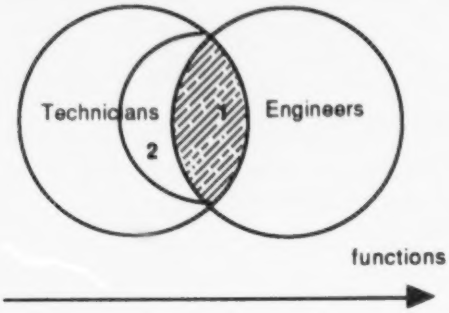
a. The technological level of the production process. Different technology levels require different combinations of skills from people employed as engineers. A mechanical engineer in a manufacturing concern that utilizes many robots will have to tackle different problems than the same mechanical engineer in a semi-automated factory.

b. The environment within which the technology functions. The functions of an engineer are affected by the working environment outside his place of work. For example, in a situation where there are technical support systems, such as firms that specialize in providing computer programming services, the engineer's knowledge of programming is less crucial than in a situation where no such support system exists.

c. The existence of individuals in other occupations who can perform partially as engineers. Skills and functions of similar occupations overlap, for example, in the case of technicians and engineers. When one of the occupations is in short supply there is room for partial substitution and a tendency to acquire functions outside the overlapping area.

In Figure 8.3, if there is a shortage of technicians, there will be a tendency to expand the engineering functions and, hence, change the composite of skills to incorporate the second area.

Figure 8.3: Overlapping Functions of Technicians and Engineers



d. The size of establishment determines the specialization of jobs. The larger the size, the more specialized the functions.

Once the composite of skills required to perform proficiently as an engineer is determined, determination has to be made on how these skills can be acquired. How much of the skills should be provided in the schools and how much in the work place.

The knowledge and skills that a graduate from an engineering school must have to function properly depend on the working environment into which he will be inducted and the proportion of inductees to the total engineering force.[1] In a situation where the existing team of engineers is of high quality, graduates of a poor quality institution will, after a while, be able to function proficiently, if their proportion in the engineering force is small. In the case where the quality of the existing team is poor, a better institutional education would be required.[2]

Assessment of the Content

The content of an engineering education must be assessed from two viewpoints: local and international.

The local viewpoint is necessary to define the skills required in the context of present day demand by the labor market. This local viewpoint is usually reflected in the opinions of employers, employed engineers, and the engineering faculty.

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[1] *If* $Q_O = f\,(Q_E, Q_T)$

$Q_T = f\,(Q_W, \frac{E}{N})$ and

Q_E and Q_T are substitutes to certain degree. Within limits the higher Q_W, less Q_E is needed for a given performance.

Q_O = Quality of performance on the job
Q_E = Quality of education
Q_T = Quality of training
Q_W = Quality of engineers at work
E = No. of engineers at work
N = New inducted engineers

[2] It is ironic that, contrary to conventional wisdom, to have an acceptable quality of engineering performance in countries where the general level of engineering proficiency is low, engineering education has to be of a higher quality than engineering education in countries with highly developed engineering services. (Of course, assuming that the same engineering functions have to be performed in both cases).

The international viewpoint is necessary to provide directions for the future. This is done by placing the characteristics of an engineering job in the country in a continuum of characteristics of engineering jobs from the less to the more advanced economies. This international viewpoint is usually offered by engineering education experts.

Quantitative Demand and Supply of Engineers

The size of the market for engineers is a major factor in determining the appropriateness of an engineering training institution. The size of the market has to be assessed in terms of spatial boundaries of the market and time.

Space

The market for engineering schools is mostly national, as contrasted to some vocational training that is mainly local. In some cases engineering schools may cater to a group of countries by design, as in the case of a multinationally sponsored school, or by *de facto* where there are recognizable migration patterns of graduates to these countries.

Time

What time horizon is appropriate for judging if the engineering school is producing the right number of graduates?

In cases 2 and 3 the time horizon is not very important. In cases 1 and 4 it makes a difference if the forecast is for t_1 or t_2. In Figure 8.4, Case 1, for example, if we confine our forecast to t_1, it would indicate that there is excess capacity in the institution. The reverse would be the conclusion for t_2.

From a forecasting point of view, the time horizon is a compromise between the desire of optimization that is more easily achieved with a short-run period, and uncertainty that grows with the length of the period.

In general, the forecast period cannot be shorter than the length of time it takes to train an engineer plus a few years, but given the nature of the investment a ten or fifteen year forecast is needed. Coincidentally, this is also an appropriate period for reflecting both structural economic changes and technological changes in industries.

From the arguments presented above it can be seen that the present labor market conditions, while still important as a base reading for a forecast, is not a major determinant of the adequacy of the capacity of an engineering school.

Methods of Forecasting Demand for Engineers

Economic forecasting is an endeavor that has failed far more often than it has succeeded.[3]

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[3] Why do economic forecasts so often fail? Mainly because of uncertainty and errors in measurements. Uncertainty arises because our knowledge is in the past sense. Knowledge of the past behavior of relevant variables, even if correct, may not be sufficient to predict random, or previously not experienced, events that may change past behavior patterns and thus affect the basic assumptions upon which the forecast is based. Even if we believe in a benign universe, which has direction and purpose—and even if we could know all the variables and measure them and their rates of change—it would still require an infinite capacity to comprehend and measure all the variables (not to mention the time to do so and to analyze the results). Since this is impossible, the best we can do is to abstract from reality a manageable list of variables and deal with this simplified "model". This puts us in a position similar to that of a person coming into a completely darkened room with some light shining into it from a preceding room. The person gazes, sees some things, but is still faced with dark and unknown areas—uncertainty. Errors in the measurement of data come not only from errors of observation but also from errors in the handling and manipulation of these observations. These are seldom made explicit, with the consequence that the illusions of accuracy, created under the guise of correctness, foster a sense of confidence in the results and not the deserved uneasiness that might lead to a search for improved data and procedures. Under these circumstances of uncertainty and errors in the data, the betting odds on the accuracy of forecasts are not encouraging.

Figure 8.4. Supply and Demand of Graduates over Time

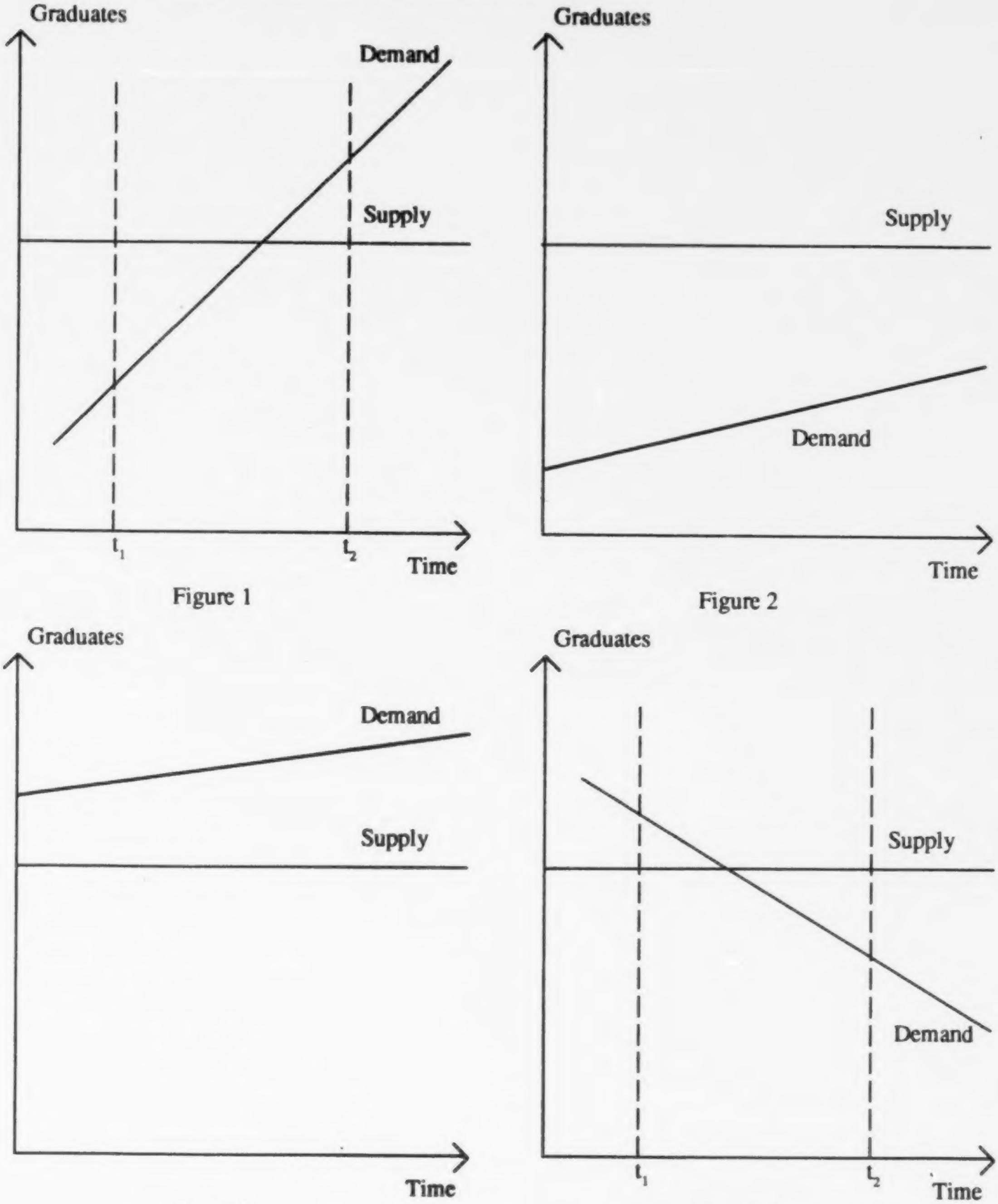

Figure 1

Figure 2

Figure 3

Figure 4

The forecasting of demand for engineers, reliant on economic forecasts, is even more vulnerable to the vicissitudes of socioeconomic processes.[4]

Nevertheless, whatever criticisms forecasters may attract, forecasts must be made if a sound basis for policy making—more rational than what would exist if forecasts were not available—is to be provided.

Broadly speaking, forecasts can be classified into three types: (1) "pure forecasts"—a guess, an extrapolation of past events, or a figure arrived at by a subjective judgement of the forecaster; (2) "conditional forecasts"—of the type "if A occurs B will follow," they center on the notion of cause and effect; and (3) "teleological forecasts"—stipulating that, in order to have B, we must provide A (in other words, as distinct from "conditional forecasts," A is not the cause of B but the means to obtain B).

Broadly speaking, forecasts can be classified into three types: (1) "pure forecasts"—a guess, an extrapolation of past events, or a figure arrived at by a subjective judgement of the forecaster; (2) "conditional forecasts"—of the type "if A occurs B will follow," they center on the notion of cause and effect; and (3) "teleological forecasts"—stipulating that, in order to have B, we must provide A (in other words, as distinct from "conditional forecasts," A is not the cause of B but the means to obtain B). Forecasting of demand for engineers uses mainly "pure" and "teleological" forecasting, singly or in combination.

"Pure" Forecasting

In its simplest form, the "pure forecast" of demand for engineers consists of the opinion of experts, or of an extrapolation over time of the number of engineers.[5] In equation form:

$$E_t = E_o + bt \text{ or } E_t = E_o (1+b)^t$$

where E_t is number of engineers at time t, E_o number of engineers at time t_o, b is the coefficient derived from historical data, and t is time.

"Teleological" Forecasting

Most manpower demand forecasts are implicitly of the "teleological" type—that is, if the economy is to achieve a given level of production and productivity, it is necessary for the labor force to have a particular occupational structure. Production does not cause a configuration of manpower, nor vice versa. Rather, a labor force with an occupational structure combines with the required capital per worker, entrepreneurship, and so forth to produce a given output and productivity. The manpower demand forecast translates an economic forecast of production or productivity (or both) into numbers of people with different occupations, or into occupational structures of the labor force. A manpower forecasts of engineers translates production and productivity of a sector or an economy into the number of engineers required.

A pragmatic approach to forecasting engineers would be to determine empirically the statistical relations, which can be derived from existing data, between the number of engineers who are employed in an industry and the output of the same industry (or between the proportion of engineers in an industry's labor force and the level of productivity in the industry).

For countries that have historical series of occupational structures and production, the calculation of these relations is straightforward.

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[4] Demand is used here to describe the number of people in different engineering occupations required to produce a given output.

[5] For example, "the numbe rof engineers will increase by 20 percent".

$$(E_j / Q_j)_t = (E_j / Q_j)_0 + f(t)$$

where E_j is the number of engineers in industry j, Q_j is production of industry j, t_0 is the initial period, and f(t) is the time trend.

Another kind of extrapolation using production as the independent variable can also be helpful in some cases:

$$(E_j / Q_j)_t = (E_j / Q_j)_0 + f(Q_j)_t$$

where statistical series of Q_j is derived from past data. Total number of engineers required would be the aggregation of industry demand for engineers across industries.

$$E_t = \sum_j E_{jt}$$

Constraints to Application

The major drawbacks of these methods for their use in developing countries are twofold. First, developing countries lack reliable and detailed historical data. Second, planning in developing countries implies a conscious effort to break with the past, therefore, trends cannot be taken as primary guidelines for future development. This is especially true if the plan contemplates the introduction of new industries.

The only way to avoid these obstacles is to use data from a variety of countries—most of which lack time series—as a basis for deriving statistical relationships.[6] Two approaches can be used to derive occupational structures from international data, the comparative approach and the statistical approach.

The Comparative Approach. If data on occupational distribution of industries covering wide ranges of productivity are available, it is possible (by deciding upon a desired level of productivity) to match an existing manpower structure (percent of engineers in the industry's labor force) or to interpolate between two known structures. For example, if country X plans to have a chemical industry with a productivity (value added per worker) of US$30,000, and available data show that the chemical industry in the United Kingdom has approximately this productivity, we can assume the occupational structure (percent of engineers in the labor force) of the chemical industry of the United Kingdom to be the one that country X will need to have for its industry.

The Statistical Approach. Parameters can be derived from different functions fitted to the data. The statistically meaningful functions can be used for determining the proportion of engineers in the labor force by industry.

When meaningful data are not available, it is more convenient to forecast the number of engineers needed in industry j on the basis of rates of growth of employment and productivity in industry j. If

$$E_j / L_j = a\, P_j^{b_j}$$

where L_j is labor force in industry j, E_j is engineers in industry j and P_j is productivity in industry j, then b_j equals the elasticity coefficient of the proportion of E_j in L_j with respect to P_j productivity in industry j:

$$bj = \frac{d(E_j / L_j)}{E_j / L_j} \Big/ \frac{dP_j}{P_j}$$

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[6] Bearning in mind the well-known drawpacks of using cross-sectional analysis at one or two points in time, rather than time series, it may also be argued that it is plausible that productutivities of industries are related to occupational structures, regardless of national boundaries.

$$E_{j_t} = E_{j_o} \exp(b_j P_j + r_j)\, t$$

where p_j is the rate of growth of productivity in industry j, r_j is the rate of growth of employment in industry j, and t = time.

Data for "b" coefficients can be calculated from two points in time in the country, or from international cross-sectional data. Some values are given in Appendix 1.

An example of the use of the equations can be given as follows. If the present number of engineers in, say, the electrical machinery industry is 500, the rate of growth of employment and productivity for these workers is forecast to be 2 and 5 percent respectively, the total number of professional and technical personnel required ten years hence will be

$$Q_W = 500 \exp(.02 + .05b)\ 10,$$

if the value b in this industry is .799 (Appendix I), then

$$Q_W = 500 \exp(.02 + .05 \times .799)\ 10, \text{ and}$$
$$Q_W = 907$$

Some Practical Steps for Forecasting Occupational Structures When b Values Are Not Available

The use of curve or function fitting to manpower and productivity data yields best results when major occupational groups such as engineers are the subject of the forecast. It is less effective when applied to three or four digit occupations such as industrial engineer or civil engineer. This is not surprising, since elasticities of substitution are smaller between, and larger within, groups. What it means is that, in order to forecast for a given occupation, we have to use "successive approximations", first by forecasting the larger group to which the occupation belongs, next the subgroup, and finally the occupation itself.

This procedure successively narrows the range of possible values that the forecast of the occupation can acquire. It also mitigates the extent of uncertainty introduced by the fact that occupational classifications are similar but not identical.[7] For example, if we wish to forecast the proportion of idustrial engineers in the labor force needed in an industry, we could follow the following steps:

a. Determine the proportion of the group "engineers" from the correlations relating to engineers and to productivity.

b. Determine the proportion of industrial engineers in total engineers within the industry by using only data of countries where this occupation is singularly defined (since the number or observations in most cases do not warrant fitting functions); an average and a high value will provide a plausible range. (Appendix 2 provides examples of values for each of the engineering occupations for the major sectors in an economy.)

c. If the purpose of the forecast is to determine the number of industrial engineers that will be required in the country, this process would have to be repeated industry by industry, sector by sector. One would hope that some of the errors would cancel each other and that the final result would be nearer to reality.

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[7] For example, in many countries the occupational title "industrial engineers" does not exist. This means that people performing the functions of industrial engineers are included among other classes of engineers—for example, mechanical engineers. It does not make sense to run correlations for industrial engineers and mechanical engineers using data from countries that lack either title in their classifications.

Capacity of an Engineering Education System

The number of new engineers or graduating engineers required at time "t" would be: [8]

$$NE_t = D_t - S_{t-1} + A_{\Delta t} - U_{\Delta t} + L_{\Delta t} + RF_t - ER_{\Delta t} + ME_{\Delta t}$$

where:

NE = new engineers
D = required engineers
S = available engineers
A = attrition due to health and retirement
U = number of technicians upgraded to engineers
L = engineers leaving the profession
RF = replacement of foreign engineers
ER = number of engineers returning from abroad
ME = number of engineers migrating abroad
t = time
Δt = t - (t-1)

In order to obtain these new engineers the number of entrants at λ (years required for training) years earlier would be:

$$EN_{(t-\lambda)} = NE_t \, (1/\alpha) \, (1+\beta)$$

where:

EN = entering students
NE = new engineers

α = efficiency coefficient = $\frac{\text{graduates}}{\text{entrants}}$ proportion of an entering class graduating.

β = proportion of graduates who do not enter the engineering profession

Required capacity of the institution can be calculated by:

$$S_t = S_{t-1} + EN_t - G_{t-1} - D_{t-1}$$

where $G_t = EN_t$

and $D_t = S_t \; x \; \delta$

$$S_t = S_{t-1} \, (1-\delta) + EN_t - EN_t - \lambda\alpha$$

S = students
EN = entering students
G = graduates
D = dropouts
δ = dropout rate
α = graduation rate

Note on Sources of Data

The methodology presented above requires different types of data. The forecast of demand for engineers requires data on production, employment, and number of engineers by industry, as well as general economic data for forecasting economic activity.

General Censuses (usually conducted every ten years), and Industrial Censuses (every five years in some countries) are primary sources of data especially if two digit industry and three digit occupational classifications are available.

When these sources are unavailable it might be necessary to have a survey to determine the density of engineers in the labor force of different industries.

The most efficient way is through a survey of engineers. Most countries have engineering associations that can furnish a list of members. A total or a sample survey can provide the data required. (A sample questionnaire is provided in Appendix 4). Existing engineers can also be identified through engineering schools. Finally, if no lists of engineers exist, the only resource is a sample survey of establishments. This latter method is usually very costly, especially in middle-size and large countries.

---

[8] The required capacity is also a function of the comparative costs of training at home or abroad (see Appendix 3).

Assessing the Efficiency of Engineering Training Institutions

Assessing efficiency, identifying inefficiencies and their causes requires quantitative analysis as well as subjective judgement. In particular, the subjective judgement has to be carried out by experienced professionals. Both types of analysis require the full cooperation of the institution's staff as well as its leaders.

The process of assessment starts with the identification of key factors that are recognized as determinants of the efficiency of a system. These are:

For the Quantitative Assessment

(a) Student Flow Rates (Appendix 5):

- Admission rate: the number of students admitted as a proportion of applicants to the course.
- Dropout rate: the number of students who leave during the course without taking final tests or examinations, as a proportion of students enrolled at the beginning of the course.
- Repetition rate: the number of students who repeat a stage of training as a proportion of the students enrolled in that stage in the previous year; and
- Pass rate: the number of students completing the course successfully as a proportion of the students enrolled in the final year or stage of the course.

(b) Student Performance (Efficiency Indexes). An overall indicator of internal efficiency in terms of student performance is found by dividing the number of graduates by the number of students entering at the beginning of the course to yield a percentage. If the amount of repetition is significant, however, it is more useful to employ a measure that indicates how much additional time over the planned time is required to produce graduates. Examples are:

- Average time required to produce a graduate: total student-years spent on training, including time spent by dropouts, divided by number of graduates produced; this can then be compared with planned time.
- Output-input ratio: the number of graduates, multiplied by planned course length in years, as a proportion of the total number of student-years spent in training.

(c) Staffing. Indicators include:

- Student-teacher ratio, by course or for the institution.
- Average class size, preferably separately for classroom work and laboratories or workshop activities.
- Average teacher workload, normally expressed as teaching hours or contact hours per week.

(d) Facility Schedules and Utilization of Space. Indicators include:

- Average area of workspace: area of classrooms, or laboratories, or workshops, divided by the normal working capacity.

- Average areas of support spaces: area of library, communal spaces, living accommodations, and the like divided by number of students using each kind of area.

- Space utilization: the actual student occupancy of total teaching space as a proportion of the total capacity of the teaching space.

(e) Costs (Appendixes 6 and 7). The most important cost measure is the cost per student per year or cost per graduate (Appendix 8). Other analyses of cost also provide valuable comparative data:

- Staff salaries as proportion of total cost.

- Cost of administration.

- Cost of student per year for consumable materials.

- Maintenance cost as proportion of capital costs.

- Student maintenance costs.

For the Qualitative Assessment

(a) Students:

- Characteristics;
- Entrance requirements;
- Student activities; and
- Student attitudes.

(b) Academic Staff:

- Characteristics.
- Staff activities.
- Staff policies.
- Staff development.

(c) Non-Academic Staff

(d) The Teaching-Learning Process:

- Curriculum;
- Teaching; and
- Examinations and assessment.

(e) Research

(f) Physical Resources:

- Libraries;
- Buildings and equipment; and
- Maintenance

(g) Management

(h) Relations with Industry.

The key factors presented above for use in quantitative and qualitative assessment of engineering programs provide a checklist for building up a profile that allows the identification of deficiencies in each of the components of the key factors. On the basis of this identification remedial action can be proposed.

To facilitate assessment of the key indicators we include two sections. The first provides detailed questions on topics relating to each of the key indicators. The second presents questionnaires for faculty, dean or head of program, graduates, and employers. The composite of answers derived from the questionnaires supplement the answers to the questions on key indicators.

STUDENTS

Characteristics

1. What is the student population?

Full time ___
Part time ___
FTE ___
Other (such as extension students) ___

2. What is the size of the student intake?

Full time ___
Part time ___
FTE ___
Other (such as extension students) ___

3. What percentage of the students is female? ___

4. Age distribution of entering students ☐ 18-20 ☐ 21+

5. How many students live on campus? ___

6. How many students live off campus? ___

7. How many students are married? ___

8. What is the social background of the students? (breakdown by income brackets) ___

Entrance Requirements

1. What are the entrance requirements to engineering programs? ___

2. If examination scores are used as a criteria for admission what are the average scores and ranges in these exams? How do they compare with scores of entrants to other careers? ___

3. Do applications exceed capacity or vice-versa? ___

4. Have there been any trends in the number and qualifications of applicants? ____________
____

5. If admission is contingent on the attainment of a previous degree, i.e., Bac—is the level attained in mathematics and basic sciences sufficient to undertake a basic engineering course?
____
____

Student Activities

1. How many hours per week are spent in class lectures? ____
2. How many hours per week are spent in laboratories? ____
3. How many hours per week are spent in class preparations and study? ____
4. How many hours per week are spent in extra curricular activities? ____
5. For commuting students how many hours per week spent in commuting ____

Student Attitudes

1. Are students satisfied with their training? ____________________
____

2. What do they think of:

Professors ____________________
Curriculum ____________________
Materials ____________________
Management of the school ____________________

3. Are students satisfied with their living conditions? ____________________
____

Characteristics of Students

	Program			*Gender*		*Age of First Year Students*			*Marital Status*			
Degree Pursued	*Full Time*	*Part Time*	*Other*	*# Males*	*# Females*	*< 18*	*18-19*	*> 20*	*Married*	*Single*	*Divorced*	*Separated*

Characteristics of Students

Degree Pursued	*Income Brackets*		
	Low	*Medium*	*High*

Admission Standards

Academic Year	Admission Exam 1		Admission Exam 2		Admission Exam 3		No. of New Students
	Minimum	Average	Minimum	Average	Minimum	Average	

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Student Activities

	Number of Hours per Week								
Year in School	Lectures	Labs	Class Prep.	Dept. Activities	Working	Extra Curricular Activities	Time on Campus Outside of Class	Profes. Engin. Groups	Time Commuting

Student Performance

Program: ______________________

	GPA					
Year	Minimum	Average	High	% 1st Time Repeaters	% 2nd Time Repeaters	Drop-Outs

Program: ______________________

	GPA					
Year	Minimum	Average	High	% 1st Time Repeaters	% 2nd Time Repeaters	Drop-Outs

Graduate Information

Year Graduated	Number of Graduates	Pursuing/Pursued Higher Education		Working		Caring for Home and Family	Unemployed
		Home	Abroad	Home	Abroad		

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ACADEMIC STAFF

Characteristics of Staff

1. How many full and part-time staff members are employed by the institution as a whole and in each department? ____________________

2. What is the hierarchical structure of each department (number of full professors, associate professors, instructors)? ____________________

3. What is the age distribution of this hierarchy? ____________________

4. What are the qualifications of the staff in terms of education, experience, locally and abroad? ____________________

5. What proportion of the staff are expatriates? and of those how many are short-term? ____________________

Activities of the Staff

1. What proportion of staff is engaged only in research? ____________________

2. How many courses does a faculty member teach a term and over a full year? ____________________

3. How much weekly faculty time is dedicated to:

   (a) Lecturing ____
   (b) Preparation ____
   (c) Correction of papers ____
   (d) Research ____
   (e) Keeping up with the field ____
   (f) Advising students ____
   (g) Administrative duties ____
   (h) Consulting ____

4. What is the average class-lecture size and the average class-laboratory size? ____________________

5. Are faculty members teaching the courses in which they specialized or attained their highest degree? ____________________

6. How many staff are engaged in sponsored research? ____________________

7. How many publications were produced in the last three years in local and foreign journals? ____________________

8. How many conferences did the faculty attend in the last three years, at home and abroad?

9. In the last three years, how many faculty members visited institutions abroad for more than one month? ____________________

10. How many faculty were seconded to industry for one month or more in the last three years? ____________________

Staff Policies

1. What is the salary scale for the faculty? ____________________

2. What are the official policies concerning:
    (a) Salaries ____________________
    (b) Promotions ____________________
    (c) Tenure ____________________
    (d) Teaching loads ____________________
    (e) Sabbaticals ____________________

(f) Travel abroad ______

(g) Conferences ______

3. How are new or replacement positions filled? ______

4. What are the policies concerning private consulting work, sponsored research, and extra compensation? ______

5. How is faculty supervised and evaluated relative to competence in teaching, research, and student advising? ______

6. What is the policy for meeting staff development needs especially in the areas of subject updating and teaching methods? ______

Supporting Academic Staff

1. How many teaching assistants does each professor have? ___

2. What functions do they perform? ______

3. How many hours a week do they assist? ___

Characteristics of Academic Staff

Department: ____________________

							Years of Post-Sec. Education		*Years of Experience*			
										Academic		
Subject Area (Teach or Research)	*Name*	*Age*	*Rank*	*Visiting or Permanent*	*Highest Degree Earned*	*Field*	*At Home*	*Away*	*Industry*	*Total*	*In This Inst.*	*FTE*
No. of areas	*No.*	*Avg. Age*	*% Dist.*	*% Visiting*	*Summary Distr. %*	*Sum. Distr. %*	*Avg. % Home*	*Avg. % Away*	*Avg./ Fac*	*Avg./ Fac*	*Avg./Fac*	*Total FTE*

Faculty Activity

		Number of Classes Taught		Distribution of Faculty Time in Hours per Week							
Name	FTE	per Term	per Term	Teaching	Class Preparation	Correcting Papers	Research	Keeping up in Field	Advising Students	Admin. Duties	Consulting

Faculty Average Salaries

Department or Unit	Professor	#	Associate Professor	#	Assistant Professor	#	Instructor	#	Teaching Assistant	#	Research Assistant	#

Average Class Sizes

Subjects			*Number of Students*	*Number of Sections*	*Average Class Size*
	Lecture	*Lab*			

Supporting Academic Staff

Department or Unit	Full-Time Faculty	Part-Time Faculty		Teaching Assistants		Graduate Students	Research Assistants	Other
		Number	FTE	Number	FTE			

NON-ACADEMIC STAFF

1. How many full-time and part-time non-academic staff are there? ______

2. What are the educational and training qualifications of the professional and technical workers? ______

3. What is the ratio of non-academic staff to faculty overall and within the various categories of non-academic staff? ______

4. What is the salary level of non-academic staff? ______

5. Is there adequate clerical and administrative support staff so the academic staff is not burdened with clerical routine work? ______

6. Are any of the non-academic jobs held by part- or full-time students? ______

Non-Academic Staff

Central Administration	Professionals	Technicians	Clerical	Skilled Service Workers	Other Service Workers
Administration					
Registry					
Computing					
Finance					
Personnel					
Buildings and Ground and Restaurants					
Library					
Sub-Total					
Departments or Units					
1.					
2.					
3.					
4.					
5.					
6.					
7.					
Sub-Total					
Total					

Qualifications of Professional and Technical Staff

Professional	*Number*	*Highest Degree Obtained*	*Years of Post Secondary Schooling*		*Years of Experience*	
Function:			*Home*	*Abroad*	*Total*	*In the Institute*
Manager						
Computer Expert						
Accountant Auditor						
Public Relations						
Librarians						
Technicians						
Laboratory						
Maintenance						
Other:						

STAFF DEVELOPMENT

1. Is there a staff development policy established at the school? If so, what are the major aims of this policy? ____________________

2. How does the institution assure the continued and improved teaching competence and professional growth of the faculty? ____________________

3. Does the institution have a Sabbatical or equivalent leave program? ____________________

4. What fraction of the faculty participates in this program? ____________________

5. How are staff development programs budgeted? ____________________

For the Last Three Years

Name	*Number of Publications*		*Number of Conferences Attended*		*Number of Visits to Foreign Inst. (More than a Month)*	*Secondment to Industry (Months)*	*Work in Sponsored Research (Months)*
	Home	*Foreign*	*Home*	*Abroad*			

CURRICULUM

1. Is the curriculum appropriate to the aims of the program, e.g., civil engineering? ______

2. Will the students emerge from the program with a firm foundation in the fundamentals and application of scientific and engineering principles that will enable them to function proficiently as engineers? ______

3. How well does the content of curricula and syllabuses satisfy course objectives? ______

4. What are the major deficiencies in the curriculum? ______

5. Is the distribution between theory and practice in the courses a balanced one? ______

6. Is the class contact or lecture time adequate to cover the course content? ______

7. How satisfactorily are different courses coordinated, sequenced? ______

8. Is the literature or reading lists of the main courses up to date? ______

9. Does the curriculum include remedial courses to make up for deficiencies in secondary education? ______

TEACHING

Description of the Process

1. What varieties of teaching approaches are used in the acquisition and transfer of knowledge at the institution? ____________________

2 What is the primary mode of teaching the courses in the institute? ____________________

3. What are the strong and weak points of the teaching methods employed in the various courses? ____________________

4. Is the interactive approach of lectures encouraged in the institute, even for large groups? ____________________

5. What forms of practical work are employed and what role does it play in the students learning process? ____________________

6. What are the strengths and weaknesses of the practical work at the institute? ____________________

7. What are the forms of tutorials or recitations that have been established? ____________________

8. Are there organized discussion classes to follow lectures? ____________________

9. What are the characteristics of these tutorials or seminars? ____________________

10. In courses which do not make use of seminars, are there appropriate means of developing the students oral skills and the students ability to work in groups? ____________________

11. How important are practical projects in the science and engineering courses? ____________________

12. How are the projects derived? Do they come from staff research, student interests? ____________________

13. What methods are used to ensure that students are steadily progressing in these projects? _

14. Are innovative approaches to develop a variety of skills in practical tasks being implemented?

Management of the Process

1. How and by whom are courses and their content determined? __________

2. How much freedom does the faculty have to design or alter courses? __________

3. What is the policy with respect to staff development in courses, seminars, supervision of theses, and practical work? __________

4. Are there institutional arrangements to promote quality of teaching? __________

5. Do a forum or organized group such as subject teams exist which meet to discuss and share teaching strategies and learning experiences? __________

6. Is scheduling of lectures, laboratory work, and seminars efficient? __________

7. Is the course work load imposed on students reasonable? __________

8. Are measures taken to even out peak loads of assignments within a semester (quarter)? __

9. Do students have self-programmed time? __________

10. For courses in which student attendance is required, how is attendance monitored? ____

11. Do students have course handbooks or subject guides to assist them in planning their course work?

12. Are students provided with introductory materials that cover topics such as development of study skills, use of libraries, seminar presentation.

13. Is the course documentation such that students are clear about the requirements of the course, its aims and objectives?

14. Are supporting materials distributed in the teaching sessions adequate?

Programs and Literature

Program	Main Subjects	Literature

EXAMINATIONS AND ASSESSMENT

1. What is the overall approach to assessment and how is it implemented? ______

2. Are assessment regulations clearly and unambiguously drafted? ______

3. How well does the assessment method in place enable students to demonstrate that they have fulfilled the objectives of the course and achieved the standards required for the degree? ______

4. Are the standards achieved by the students appropriate to higher education and do they compare to similar courses elsewhere, both within the region and internationally? ______

5. How well does the examination scheme relate to course objectives? ______

6. How satisfactory are the arrangements for determining passing or failure? ______

7. What is the emphasis in the examinations? (factual recall, theoretical understanding) ______

8. What are the criteria for grading students? (normal distribution, percent of correct answers) ______

9. Are there external examiners and, if so, what is their role? ______

RESEARCH

1. Does the institution have a research policy? ____________________

2. Which are the strongest areas of research in the engineering school? ____________________

3. Approximately how many research projects have been conducted in the last three years? ____________________

4. Of these projects how many were funded by own resources, and how many from external sources? In what amounts? ____________________

5. How does the standard of the research performed compare with that of the region and internationally? ____________________

6. Are any members of the faculty required to undertake research? ____________________

7. What percent of the staff is actively engaged in research, either alone or in teams? ____________________

8. Is research a major consideration in the promotion or recognition of a faculty member? ____________________

9. How does research impact students? ____________________

Research

Year (Start From Most Recent Year)	Department	Title/Subject Area	Time (years)	Principle Staff Involved	Amount Funded by Inst. ($)	External Source Funding	
						Name	Amount
		Total Number		Total (Only Count Once)	Total		Total

Students and Research

	Masters			Doctorates			Research Assistantships	Funding for Assistantships	
Department	Full Time	Part Time	Other	Full Time	Part Time	Other		Name of Funding Organization	$ Amount
	Total	Total	Total	Total	Total	Total			
	% Dist.	% Dist.	% Dist.	% Dist.	% Dist.	% Dist.			

Research Affiliations

Research Organization or Institution or Institution etc.	Relation to Research and Engineering Program

BUILDINGS AND EQUIPMENT

Buildings

1. What teaching facilities are available?

	No.	Area	Student places
Classrooms	___	___	___
Laboratories and workshops	___	___	___
Preparation rooms and stores	___	___	___

2. Are the physical layout and interrelationship satisfactory? ____________________
   ____

3. Is the provision of faculty offices and meeting rooms adequate? ____________________
   ____

4. How satisfactory is the utilization of:
   Classrooms ____
   ____

   Laboratories and workshops ____
   ____

5. Are services adequate? ____
   ____

6. Are buildings well maintained? ____
   ____

7. Are safety features satisfactory? ____
   ____

8. Are lighting and ventilation satisfactory? ____
   ____

9. Are the buildings secured well to prevent vandalism and theft? ____________________
   ____

Equipment

1. How relevant is the equipment to course needs? ____________________

2. How comprehensive is the range of the equipment? ____________________

3. Is the equipment up-to-date? ____________________

4. How adequate are the provision and availability of the following support equipment?

   Overhead projectors ____________________

   Reprographic equipment ____________________

   Other audio visual aids ____________________

5. How satisfactory is the utilization of equipment? ____________________

6. What is the main reason for equipment not being in regular use?

   Lack of materials ____________________

   Not relevant to course needs ____________________

   Obsolete ____________________

   Broken down: lack of spares ____________________

7. What is the personnel provision for maintaining and servicing laboratory equipment? ____________________

8. Are there sufficient budgetary provisions for maintaining and servicing equipment? ______

9. Are materials available in sufficient quantity for teaching and training? ______

10. How satisfactory are stocks of consumable materials? ______

11. Are there satisfactory provisions in annual budgets for replacing materials? ______

Computer Facilities

1. What computer facilities are available? ______

2. How many computers and what type are in each computer laboratory? ______

3. How is student access to the computer facilities provided and monitored? ______

4. How are the computer facilities accessed by faculty? ______

5. Provide an assessment of the limitations on the education of engineering students resulting from the current computer facilities. ______

Equipment and Facilities

Physical Facility (Building and Room Number)	Purpose of Laboratory Including Courses Taught	Condition of Laboratory	Adequacy for Instruction	Number of Student Stations	Area (Sq. Meters)
					Total Area:

Equipment and Facilities

Physical Facility (Building and Room Number)	*Laboratory Equipment Available*	*Condition of Equipment*	*Staff Needs for Maintenance/ Instruction*	*New Equipment Purchased in the Last Six Years*

Space Utilization

Instructions: Provide information for each column (see also example that follows this form).

Col. 1. List spaces by type of use or specialization; for example, classrooms (could be treated as group), drawing offices, laboratories (by specialization, as electrical engineering, mechanical engineering, physics), workshops (by specialization, as mechanical, bench, machine, electrical).

Col. 2. Enter number of workplaces for each group of specialized spaces (from D.5, col.4).

Col. 3. For the theoretical, or maximum, capacity, multiply the number of workplaces by the hours (or periods) per week that the center or school is open and multiply the products by the number of weeks per year (or semester) that the center or school is open.

Col. 4. For each group of specialized spaces list by year the courses that actually use that facility.

Col. 5. Enter the actual number of students enrolled in the course of the year (or semester).

Col. 6. Enter the hours (or period) per week when students are actually scheduled to be seeing the facility (from the course curriculum).

Col. 7. Enter the number of weeks per year (or per semester) when the course actually uses the facility.

Col. 8. Multiply (5) by (6) by (7).

Col. 9. Divide (8) by (3).

Teaching Space(s) (1)	*No. of Workplaces (2)*	*Capacity in Place-hours (or Periods) per Year (or Semester) (3)*	*Course(s) Using the Facility (4)*	*Number of Students Enrolled in Each Course (5)*	*Hours (Periods) per Week Spent in the Facility (6)*	*Number of Weeks per Year (or Semester) for which Course Uses Facility (7)*	*Actual Use in Student-Hours (or Periods) Per Year (or Semester) (8)*	*Utilization Factor (9)*

This example illustrates the method for calculating utilization of a mechanical workshop and a physics laboratory where these facilities are used by two courses, a mechanical course and an electrical course.

Teaching Space (1)	*Courses Using Facility (4)*	*Number of Students Enrolled (5)*	*Hours or Periods per Week Spent in Facility* [a] *(6)*	*Number of Weeks per Year Facility Used (7)*	*Actual Use in Student-hours per Year ((7)-(6)-(5)) (8)*
Mechanical Workshops	Mechanical				
	First year	50	6	36	10,800
	Second year	40	8	36	11,520
	Third year	38	12	36	16,416
	Electrical				
	First year	25	2	36	1,800
	Second year	23	2	36	1,656
Total					42,192
Physics Laboratory	Mechanical				
	First year	50	4	36	7,800
	Second year	40	4	36	5,760
	Third year	38	4	36	5,472
	Electrical				
	First year	25	4	36	3,600
	Second year	23	4	36	3,312
	Third year	26	4	36	3,744
Total					29,088

Notes: columns numbers correspond to numbers in D.6. For this example we assume a course length of 36 weeks per year.

[a] This information is derived from the school curricula, as shown below (number in italics correspond to column 6 in the example).

Source: Hunting, G., Zymelman, M. and Godfrey, M. 1986. Evaluating Vocational Training Programs: A Practical Guide. Washington, D.C., World Bank. pp.64-64.

(Hours per Week) Curriculum	Mechanical Course First Year	Mechanical Course Second Year	Mechanical Course Third Year	Electrical Course First Year	Electrical Course Second Year	Electrical Course Third Year
Mathematics	6	6	6	6	6	6
Social Studies	4	3	2	4	3	2
Physics:						
Lab	4	4	4	4	4	4
Theory	2	2	2	2	2	2
Chemistry:						
Lab	4	3	2	4	3	2
Theory	2	2	1	2	2	1

Curriculum	Mechanical course First year	Mechanical course Second year	Mechanical course Third year	Electrical course First year	Electrical course Second year	Electrical course Third year
Mechanical:						
Workshop	6	8	12	2	2	0
Theory	4	4	6	1	1	0
Electrical:						
Workshop	2	2	0	6	8	12
Theory	1	1	0	4	4	6
Total	35	35	35	35	38	35

Utilization of Equipment

Instructions: Complete for each laboratory or workshop inspected

	What Percentage of Equipment is		*If Answer to (3) is Less Than 70 Percent, This is Because of*						*Is There a Regular Scheme For Recording Utilization of Equipment?*		*Is There a Regular Maintenance Program?*		*Give Details of Any*
Laboratory or Workshop (1)	*In Good Working Order (2)*	*Used Regularly (25 Hours or More a Week)*	*Shortage of Materials*	*Lack of Spare Parts*	*Lack of Instruments*	*Inappropriate Equipment*	*Obsolete Equipment*	*Other*	*Yes*	*No*	*Yes*	*No*	*Major Problems With Utilization of Equipment*

Upkeep of Laboratories

Laboratory	No. of Student Places	Structural Condition; Roof, Walls, Floors, Windows	Condition of Paint; Walls, Windows, Doors	Cleanliness of Floors	Internal Order; Work Flow, Equipment	Electrical and Gas Installations	Safety and Fire Equipment	First Aid and Fire Equipment	Lighting	Ventilation, Temperature	Overall Assessment
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P	E G F P

Note: E = Excellent; G = Good; F = Fair; P = Poor

Upkeep of Classrooms

Classrooms	*Structural Condition; Roof, Walls, Floors, Windows*	*Condition of Paint; Walls, Windows, Doors*	*Cleanliness of Floors*	*Safety and Protection*	*Lighting*	*Ventilation, Temperature*	*Overall Assessment*
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P
		E G F P	E G F P	E G F P	E G F P	E G F P	E G F P

Note: E = Excellent; G = Good; F = Fair; P = Poor

LIBRARIES [a]

Building and Equipment

1. Are the buildings sufficient to house staff and collections? ________

2. How many buildings house the library and what are the conditions of these buildings? ________

3. Are the buildings adequately maintained? ________

4. What are the opening and closing hours of the buildings? ________

Library Capacity

1. What is the total space of the library? ________

2. How many study spaces does it provide? ________

3. How much reading space is available? ________

4. How many books (volumes) is it capable of shelving? ________

5. How many books (volumes) is it presently shelving? ________

Collection and Books

1. How many volumes, periodicals, and slides does the library stock? ________

2. How many volumes per FTE student does the library have? ________

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[a] This section applies if there is a separate engineering library.

3. Does the collection, both technical and non-technical, include books, journals, and other reference material for collateral reading in connection with the instructional and research programs and professional work? ______

4. Are the library collections reasonably complete and do they go well beyond the minimum collection required for use by students including those in specialized programs? ______

5. Is there a minimum of current periodicals, with back runs of no less than ten years, and a range of other reference materials? ______

6. Do the periodicals include some journals from different countries? ______

7. Which areas have dated material or insufficient titles? ______

Equipment

1. Is the range, quantity, and location of equipment adequate to the programs offered? ______

2. Are there computer facilities in the library? ______

3. Is the equipment adequately maintained? ______

4. Is there evidence of planning for the use of new and improved technologies in the library facilities? ______

Library Policies

1. Is there a written policy for managing the collection? ______

2. Is there a procedure in use to insure rapid circulation among users? ______

3. Are the collections available for use with the assistance of staff, or through an open-stack arrangement, or both? ______

4. What basis is used for determining collection levels and sizes? ______

5. Is there appropriate provision for the review of the current collections? ______

6. Does the library collection reflect the existence of an active acquisition policy; this policy should include specific acquisitions on the request and recommendation of the faculty of the engineering unit? ______

Collection Use

1. How much is the collection used? ______

2. Approximately how many registered student users and external users are there in a year? ______

3. What posts of the collection and resources are in highest demand which may prevent many users from access to the collection (such as pressure on periodicals for research interests)? ______

4. How available and helpful are the staff in making the material accessible? ______

Human Resources

1. What is the size of the library staff? ______

2. How many professional librarians are there? ______

3. How is the staff organized? (For example, are they divided into specific groups to perform tasks such as acquisitions, cataloguing, media, circulation services, subject specialist information and guidance?) ______

4. Is the proportion of professional and support staff appropriate to the function served? ____

5. Is there an established staff development program for maintaining and improving the education and skills of the library staff? ____

6. Does the library staff communicate often with the teaching staff? ____

Budget

1. Are the budgetary resources sufficient to support current activities and to provide for future development? ____

2. Is the school allocating adequate funds to the purchase of books, periodicals and other resources? ____

3. What percent of the school expenditures is represented in the library funding? ____

4. What is the balance between the purchase of books for teaching and periodicals and other materials for research? ____

5. Is there a budgetary provision for upgrading, repair, or replacement of the equipment? ____

Preservation, Conservation, and Replacement

1. Does the library have proper environmental controls? ____

2. Does the library have an emergency plan? ____

3. Does the library budget have adequate provision for the preservation and repair of damaged, aged, and brittle books? ____

4. Does the library have adequate safeguards against loss, mutilation, and theft? ____________

5. How many books are lost every year and what percent of the materials purchased in a year are for replacing lost materials? ____________

6. What is the criteria used for the resource replacement and development program for the library? ____________

Planning

1. Does the institution include library participation in its planning process? ____________

2. Are there plans for future library development? ____________

3. Is the mechanism for making these plans adequate? ____________

4. Do the plans show appropriate consultation within the institutions? ____________

LIBRARY [10]

Collection and Books

1. How many volumes, periodicals in engineering fields does the library have? ______

2. Does the collection include books, journals, and other reference materials for collateral reading related to instruction, research, or professional work? ______

3. Is the engineering collection reasonably complete, beyond the minimum collection required for use by students? ______

4. Is there a minimum of current periodicals with back runs of no less than ten years, and a range of other references? ______

5. Do the periodicals include some journals from different countries? ______

6. Which areas have insufficient titles or dated materials? ______

Collection Use

1. How much is the engineering collection used? ______

2. What parts of the collection are in highest demand which may prevent users from having access at the required time? ______

3. How available and helpful are the library staff in making the material accessible? ______

4. What provisions are taken to prevent the loss of materials? ______

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[10] When the engineering library is part of the general library.

Budget

1. Is the budget for the engineering collection determined by the engineering school in conjunction with the central administration? ____________________

2. Is the engineering department responsible for allocating funds for the purchase of books periodicals and other resources? ____________________

3. What percent of the operating budget for the engineering schools is allocated to the library?
____

Library Facilities and Expenditures

					Staff		*Users*	
Building or Facility	***Total Space***	***Study Space***	***Volume Capacity***	***Present Volumes***	***Prof. Library***	***Others***	***Student Users***	***Outside Users***

Library Resources and Acquisitions

	Acquisitions During Last Three Years		*Current Collection Resources*	
	Books	*Periodicals*	*Books*	*Periodicals*
Entire Institutional Library				
In the Following Fields (Including Above)				
Chemistry				
Mathematics				
Physics				
Other Specialty Areas (Specify)				

Library Expenditures

	(Year)	*(Year)*	*(Year)*
Total Library Current Funds			
Expenditures For:			
Books			
Periodicals			
Other Engineering Related Services			
Operating Expenditures			
Repair/Replacement of			
Books and Collections			
Equipment			
Other			
Staff Expenditures			
Professional Librarians			
Others			

MANAGEMENT

(a) Is there a plan covering:

Enrollment

Staffing

Physical Resources

Financial Resources

(b) How often are plans reviewed, monitored?

(c) How adequate is the information system dealing with:

Students

Expenditures

Utilization of resources

Courses and grades

Staff

(d) Is the information used in decision making?

(e) Style of management:

Authoritarian

By consensus ____

By committee ____

Other (describe) ______________________________________

RELATIONS WITH INDUSTRY AND OTHER INSTITUTIONS

1. Does the school have links with other engineering schools in the region, continent and abroad?

2. What is the impact of these relationships on the educational process?

3. Are there any links with the local production sector. private and public?

4. In what form does the production sector interact with the school?

   (a) Provides advice

   (b) Supplies part-time faculty

   (c) Has cooperative arrangements with the school for students to be placed in industry as part of training

   (d) Provides consulting opportunities to faculty staff

   (e) Sponsors students

5. How effectively does the institution provide to industry technical advice, technical services, and production assistance?

6. How effective is the institution in helping students and graduates to obtain employment in the productive sector?

7. Do prospective employers visit the institution to recruit engineers?

8. How effective is the institution's follow-up of graduates to obtain feedback information on their training and employment?

QUESTIONNAIRE

Questionnaire for Employers

Name of Company or Department ______________________________

☐ INDUSTRY ☐ GOVERNMENT

Number of Workers ☐ 50-200 ☐ 200-500 ☐ 500+

Number of engineers: ____

1. Approximately how many engineers did you hire in the last three years?
   Type: Electrical engr., Civil engr., etc.
   (a) Less than 3 ____
   (b) 3 - 5 ____
   (c) 5+ ____

2. How did you recruit these engineers?
   (a) Advertise in newspapers ____
   (b) Use word-of-mouth ____
   (c) Contact the engineering school ____
   (d) Other ____

3. How many applicants did you get for every job opening? ____

4. Which of the following criteria did you use when hiring new engineers?
   (a) Reference from previous employer ____
   (b) Reference from other engineers in the firm ____
   (c) Reference from Engineering School ____
   (d) Interview and/or test given in the firm ____
   (e) Other ____

5. Among those hired are there graduates from the local engineering school? ☐ YES ☐ NO

   If yes: ______________________________

6. How do you rate the following in the engineers you hired?

	Poor	Fair	Good	Excellent
Theoretical knowledge	___	___	___	___
Practical knowledge	___	___	___	___
Ability to solve engineering problems	___	___	___	___
Speed of learning new concepts	___	___	___	___
Speed of learning how to do things	___	___	___	___
Willingness to do manual work	___	___	___	___
Interest in work	___	___	___	___
Motivation to do the job	___	___	___	___

7. Overall, which of the following best describes this employee's job performance:

☐ Poor ☐ Fair ☐ Good ☐ Excellent

8. Overall, to what extent does this employee possess the characteristics you would expect from an engineering school graduate?

☐ Does not meet my expectations ☐ Meets my expectations ☐ Exceeds my expectations

9. If you are acquainted with the proficiency levels of expatriate engineers, how do you compare the graduates with them? They are:

☐ better ☐ the same ☐ poorer

10. In which area:
    (a) Theoretical ___
    (b) Practical knowledge ___
    (c) Ability ___
    (d) Willingness to do manual work ___

11. If you could influence the education of engineers in your country what would you suggest?
    (a) Teach students to solve problems ___
    (b) Think creatively to solve problems ___
    (c) Provide more practical knowledge ___
    (d) Provide more theoretical knowledge ___
    (e) Demand practical experience before granting a degree ___
    (f) Increase technical skills ___
    (g) Provide business courses ___

12. How valuable is each of the following areas to the successful job performance of the engineers you hired in the last three years.

		Not at all valuable	Somewhat valuable	Very valuable
(a)	Courses specific to area of employment	___	___	___
(b)	An internship, co-op or field experience	___	___	___
(c)	Courses in mathematics	___	___	___
(d)	Courses in computers	___	___	___
(e)	Courses in business	___	___	___
(f)	Courses in foreign language	___	___	___

13. How important is each trait to successful job performance?

		Not important	Somewhat important	Very important
(a)	Planning projects	___	___	___
(b)	Defining problems	___	___	___
(c)	Solving problems	___	___	___
(d)	Thinking creatively	___	___	___
(e)	Processing and interpreting data	___	___	___
(f)	Applying job-related technical skills	___	___	___
(g)	Working cooperatively	___	___	___
(h)	Leading others	___	___	___

QUESTIONNAIRE FOR THE DEAN OF THE ENGINEERING SCHOOL

Name: ____________________

Age: ____________________

Education: Home ____________________

Abroad ____________________

Post degree training: ____________________

Work experience: Industry ____________________

Academia ____________________

Recruitment and Employment of Academic Staff:

1. In your opinion, is it possible to recruit an adequate number of local qualified staff? ☐ YES ☐ NO

   If No, why? ____________________

   ____

   (a) Pay is too low to attract qualified people ____
   (b) There are no qualified people especially for senior positions ____
   (c) Other ____

2. What percent of your staff is expatriate? ____

3. Do you have a plan to replace expatriates? ☐ YES ☐ NO

   If yes ____________________

   ____

4. What do you intend to do?
   (a) Send junior faculty to be trained abroad ____
   (b) Try to attract qualified nationals from abroad ____
   (c) Send engineering graduates to get higher degrees abroad ____
   (d) Develop a local graduate program ____
   (e) Other ____

5. In your experience, what percentage of faculty and students completing advanced degrees abroad return home?
   (a) 5% - 10% ____
   (b) 11% - 25% ____
   (c) 26% - 50% ____
   (d) 51% - 75% ____
   (e) 75+% ____

6. In your judgement, how satisfactory is the performance of your staff?
   (a) Staff as a whole is in need of upgrading ____
   (b) Most staff need additional training and more experience ____
   (c) Some staff need more training and experience ____
   (d) Satisfactory ____

7. If staff need more training or experience, in what areas?
   (a) Professional or technical knowledge ____
   (b) Practical knowledge ____
   (c) Experience in the world of work ____
   (d) Ability to teach ____
   (e) Other ____

Quality of Output and Graduates

8. Are graduates from your program prepared satisfactorily for employment in fields relevant to their training? ☐ YES ☐ NO

9. If No, why?
   (a) Time is too short to cover all necessary subjects ____
   (b) Instructors are not well trained ____
   (c) Instructors lack practical experience ____
   (d) Students are not sufficiently motivated ____
   (e) Content of courses not always relevant to employment needs ____
   (f) Facilities and equipment are below standard ____
   (g) Other ____

Management

10. For each of the following, check Y if the school or department is directly responsible for that activity. If No is checked, indicate the body (for example, central administration of the university) that is responsible.

    (a) Recruitment of faculty ______ ☐ YES ☐ NO

    (b) Recruitment of support staff ______ ☐ YES ☐ NO

(c) Admission and/or selection of students ______ ☐ YES ☐ NO

(d) Design of curricula and syllabuses ______ ☐ YES ☐ NO

(e) Adaptation of curricula and syllabuses ______ ☐ YES ☐ NO

(f) Revision of curricula and syllabuses ______ ☐ YES ☐ NO

(g) Preparation of teaching and training materials ______ ☐ YES ☐ NO

(h) Design of examinations or tests ______ ☐ YES ☐ NO

(i) Purchase of equipment ______ ☐ YES ☐ NO

(j) Purchase of consumable materials ______ ☐ YES ☐ NO

(k) Scheduling of classes ______ ☐ YES ☐ NO

Records

11. For each, check if the school is responsible for collecting and maintaining the following records:

(a) Does the school have records on the selection and admission of students ☐ YES ☐ NO

(b) Are records kept in school of students performance and examinations ☐ YES ☐ NO

(c) Are faculty staff and support staff records kept in school ☐ YES ☐ NO

(d) Are the following teaching records available for examination?

Curricula ☐ YES ☐ NO

Course programs ☐ YES ☐ NO

Examinations ☐ YES ☐ NO

Examination - grades ☐ YES ☐ NO

(e) Are the following financial records available for examination?

Faculty staff salaries ☐ YES ☐ NO

Support staff salaries	YES	NO
Expenditure on consumable materials	YES	NO
Maintenance costs of bldgs. & equpt.	YES	NO
Utilities	YES	NO
Other recurrent expenditures	YES	NO
Capital expenditures on buildings and equipment	YES	NO

Planning

12.	Is medium or long term planning used in the school?	YES	NO

13. What is the planning structure?
    (a) Permanent planning committee ____
    (b) Ad hoc faculty planning committee ____
    (c) Ad hoc external and faculty committee ____

14.	Are financial analyses (for example, trends in cost/student, cost/graduate, structure of costs) used in the management and planning of the school?	YES	NO

General

15. In your opinion which three of the following measures would most improve the training in your institution.
    (a) Improve buildings ____
    (b) Improve laboratories and equipment ____
    (c) Change the structure and/or content of curriculum ____
    (d) Increase and improve class materials and books ____
    (e) Increase faculty ____
    (f) Improve quality of the faculty ____
    (g) Raise admission requirements for applying students ____
    (h) Foster close relations with employers ____
    (i) Have a twining arrangement with a university abroad ____
    (j) Other (explain) ____

____

QUESTIONNAIRE FOR PROFESSORS

Age: ______________________

Position Held: ______________________

Subject Area: ______________________

1. What school did you attend to receive your undergraduate degree?
   a. School in home country ___
   b. School in other African countries ___
   c. Outside Africa ___

2. What degree(s) did you receive as an undergraduate student?

   At home: ______________________

   Abroad: ______________________

3. What degree(s) did you receive as a graduate student?

   At home: ______________________

   Abroad: ______________________

4. Have you had any training/experience abroad?

   a. Work in industry - where and how long ______________________

   b. Post-doctorate research - institute and research done ______________________

5. Have you taught at any other higher learning institutes? ☐ YES ☐ NO

6. If yes, where and how long, please list each.

At home: ____________________

Abroad: ____________________

Teaching

7. How many years have you been a professor at this institute? ____

8. What do your duties consist of?
   - a. Personal research ____
   - b. Preparing for lecture ____
   - c. Lecturing/teaching ____
   - d. Advising students ____
   - e. Correcting papers/exams ____
   - f. Administrative meetings ____
   - g. Consulting ____
   - h. Other ________ ____

9. What subject(s) do you teach? ____________________

10. Are you teaching in your area of specialization? YES NO

11. How many classes do you teach per term? ____

12 Is the teaching load?
   - a. Too large ____
   - b. Manageable ____

13. In your opinion is scheduling of lectures, laboratory work, and seminars
   - a. Efficient ____
   - b. Slightly efficient ____
   - c. Inefficient ____

14. How adequate is the class contact/lecture time to cover the course content?
   - a. Adequate ____
   - b. Inadequate ____

15. What is the main form of teaching you use?
    - a. Lectures ____
    - b. Seminars ____
    - c. Laboratory demonstration ____
    - d. All of the above ____

16. Considering the class sizes, how is the interaction with the students during the lecture?
    - a. Very good ____
    - b. Good ____
    - c. Poor ____
    - d. Non-existent ____

17. Are there enough professors in the department to cover the necessary teaching duties and conduct research?
    - a. Not enough ____
    - b. An adequate number of teaching staff ____
    - c. The teaching staff is too large ____

18. How many time do you have available to meet with and assist students outside the lectures?
    - a. None ____
    - b. A little ____
    - c. A lot of time ____

19. Are you aware of any institutional arrangements to promote quality of teaching? ☐ YES ☐ NO

20. If yes, are there workshops or classes to assist the professors to improve their teaching skills? ☐ YES ☐ NO

21. If yes, have you ever attended one of these workshops? ☐ YES ☐ NO

22. Did you find the workshops or classes helpful?
    - a. Yes ____
    - b. Somewhat ____
    - c. Not at all ____

23. How much freedom are you given to teach a class?
    - a. None ____
    - b. Some but not enough ____
    - c. A sufficient amount ____

24. Do you agree that the financing staff is given enough time and opportunities to improve their technical knowledge and practical skills?
    a. Strongly agree ____
    b. Agree ____
    c. Disagree ____
    d. Strongly disagree ____

Curriculum

25. Who determine the course content?
    a. Professor/teacher ____
    b. Department ____
    c. Special teams ____
    d. Administration ____

26. Do you create your own curriculum ☐ YES ☐ NO

27. Is the curriculum copied from abroad? ☐ YES ☐ NO

28. Is the curriculum appropriate to the aims of the program, i.e., civil engineering?
    a. No ____
    b. Partially ____
    c. Yes ____

29. The content of curricula and syllabuses satisfy course objectives
    a. Poorly ____
    b. Fairly well ____
    c. Very well ____

30. Is literature or reading lists provided for the main courses?
    a. Never ____
    b. Sometimes ____
    c. Often ____
    d. Always ____

31. How up to date are the literature and reading lists?
    a. Not at all ____
    b. Somewhat ____
    c. Up to date ____

32. In your opinion, how is the balance between theory and practice in the courses?
    a. Poor ___
    b. Fair ___
    c. Good ___
    d. Excellent ___

33. Is the course curriculum adjusted on a regular basis to keep up with the latest developments in the field?
    a. Not at all ___
    b. A little ___
    c. Some ___
    d. Yes, on a regular basis ___

34. How satisfactorily are different courses coordinated or sequenced?
    a. Poor ___
    b. Fair ___
    c. Good ___
    d. Excellent ___

35. Are there remedial courses to make up for deficiencies in secondary education? ☐ YES ☐ NO

36. How successful are these courses in preparing the student for the regular curriculum of the program?
    a. Not successful ___
    b. Partially successful ___
    c. Successful ___

Examination and Assessment

37. Does each course have its own separate examinations? ☐ YES ☐ NO

38. If yes, in general how often are the examinations given in the courses?
    a. Once per term ___
    b. Twice per term ___
    c. Three times per term ___
    d. Other ________________ ___

39. If no, are the examinations given regularly according to the programs? ☐ YES ☐ NO

40. If yes to the above question, how often are the program examinations given?
    a. Once per term ____
    b. Twice per term ____
    c. Three times per term ____
    d. Other ____________ ____

41. Who writes the examinations?
    a. The professor ____
    b. The department ____
    c. The administration ____
    d. External examiners ____
    e. Other ____________ ____

42. What is the general format of the examinations?
    a. Multiple choice ____
    b. Fill in the blank ____
    c. Problem solving ____
    d. Other ____________ ____

43. What is the emphasis in the examinations?
    a. Factual recall ____
    b. Theoretical understanding ____
    c. Applications ____
    d. Other ________________ ____

44. What is the criteria for grading students?
    a. Normal distribution ____
    b. Straight distribution ____
    c. Percent of correct answers ____
    d. Other ________________ ____

45. What is the criteria for advancing students on to the next course?
    a. Normal distribution ____
    b. Straight distribution ____
    c. Percent of correct answers ____
    d. Number of spaces available in next class ____
    e. Other ________________ ____

46. Are there external examiners? ☐ YES ☐ NO

47. If yes, how qualified are they to assess the students abilities in the subject area?
    a. Very well qualified ____
    b. Adequately qualified ____
    c. Not qualified ____

48. In your opinion, how well does the assessment method in place enable students to demonstrate that they have fulfilled the objectives of the course and achieved the standards required for the degree:
    a. Poorly ___
    b. Fairly well ___
    c. Very well ___

Materials

49. What are the main sources you draw upon for your teaching materials?
    a. The course text ___
    b. Your own texts and books ___
    c. Your own knowledge about the material ___
    d. Other ________________ ___

50. Are the amounts of class printed materials available to the students/professors?
    a. Adequate ___
    b. Somewhat adequate ___
    c. Inadequate ___

51. How is the printed material for the course chosen?
    a. By the professor ___
    b. By the department responsible for the course ___
    c. By the administration ___
    d. There is no choice ___

52. What do the students use for their course materials?
    a. Required course text ___
    b. Reading list ___
    c. Handouts ___
    d. Printed notes ___
    e. Their own notes ___
    f. Listening to the lecture ___
    g. Other ________________ ___

53. In general, is each student provided with a textbook for the courses at the institute?
    a. Always ___
    b. Most of the time ___
    c. Seldom ___
    d. Never ___

54. Does the engineering library contain a sufficient amount of materials (texts, periodicals, etc.) relating to your field?
   a. No ___
   b. Marginally sufficient ___
   c. Sufficient ___

Students

55. On average how many students are in your undergraduate lectures/classes?
   a. < 20 ___
   b. 20-40 ___
   c. 40-60 ___
   d. 60-80 ___
   e. 80-100 ___
   f. > 100 ___

56. On average how many students are in our graduate lectures/classes?
   a. < 20 ___
   b. 20-40 ___
   c. 40-60 ___
   d. 60-80 ___
   e. 80-100 ___
   f. > 100 ___

57. What is the range of the number of students in the laboratory sections?
   a. 10-15 ___
   b. 15-20 ___
   c. 20-25 ___
   d. 25-30 ___
   e. 30-40 ___
   f. 40-50 ___
   g. > 50 ___

58. How prepared are the students to handle the material upon entering the university or institute?
   a. Poor ___
   b. Fair ___
   c. Good ___
   d. Excellent ___

59. Do you feel that the admissions standards are:
   a. Good ___
   b. Adequate ___
   c. Too low ___

60. How would you rate the students study habits?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

61. From your experience, how prepared are the students when they come to lecture/class?
    a. Not at all prepared ____
    b. A little prepared ____
    c. Well prepared ____

62. How interested are the students in learning the materials?
    a. Not at all ____
    b. A little ____
    c. Very interested ____

63. How motivated are the students in learning the material?
    a. Poorly motivated ____
    b. Fairly motivated ____
    c. Highly motivated ____

64. At the end of the course, what is the students knowledge of the course material?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

65. Upon graduating how prepared are the students to work in their profession?
    a. Poorly prepared ____
    b. Adequately prepared ____
    c. Very well prepared ____

66. Do you agree that industrial experience should be compulsory for the students?
    a. Strongly disagree ____
    b. Disagree ____
    c. Agree ____

67. What the the possibilities of the students finding employment upon graduating?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

68. What percentage of the students are capable of pursuing a higher degree?
a. < 5% ____
b. 5-10% ____
c. 10-15% ____
d. 15-20% ____
e. >20% ____

69. In your estimation, what are the major reasons for students dropping out of the program?
a. Not motivated to do the work ____
b. Do not like the subject matter ____
c. Found the work/subject matter to be too difficult ____
d. Did not have the necessary financial support ____
e. Needed to get a job to support self or family ____
f. Other ______________________ ____

70. Are there graduate students at the institute? ☐ YES ☐ NO

71. If yes, have you ever been an advisor to graduate students?
a. Never ____
b. A few times ____
c. Frequently ____

72. What is your opinion of the graduate students at the institute?
a. Have good knowledge base and work hard ____
b. Good knowledge base but do not work hard ____
c. Work hard but have poor knowledge base ____
d. Poor knowledge base and do not work hard ____
e. Other ______________________ ____

73. How would you rate the graduate programs at the institute?
a. Poor ____
b. Fair ____
c. Good ____
d. Excellent ____

74. Are the graduate students supplied with the necessary office space to conduct their research and perform any other duties they may have?
a. Yes ____
b. They have a little space, but they must share it ____
c. No ____

75. What is the quality of the research conducted by the graduate students?
    - a. Poor ____
    - b. Fair ____
    - c. Good ____
    - d. Excellent ____

76. Do the graduate students have access to equipment professor research?
    - a. Yes ____
    - b. They share equipment with their advising professor ____
    - c. There is little to no equipment available ____

77. Are the graduate students supplied with offices?
    - a. Yes, private offices ____
    - b. Shared offices ____
    - c. No ____

78. What are the duties of the graduate students?
    - a. Recitations ____
    - b. Teaching ____
    - c. Office hours ____
    - d. Grading papers ____
    - e. Research assisting ____
    - f. Taking classes ____
    - g. Doing their own research ____
    - h. Other ________________ ____

79. Should the graduate students have more practical experience?
    - a. No, it is not necessary ____
    - b. More experience would be valuable but not necessary ____
    - c. Yes ____

80. Is there compulsory work in industry during the graduate education period? ☐ YES ☐ NO

81. What are the possibilities of the graduate students finding employment upon graduating?
    - a. Poor ____
    - b. Fair ____
    - c. Good ____
    - d. Excellent ____

Facilities

82. How would you describe the lecture rooms?
    a. Too large for the class size ____
    b. The right size ____
    c. Too small for the class size ____

83. Which of the following teaching aids are available in the classrooms?
    a. Blackboards ____
    b. Overhead projectors ____
    c. Equipment for lecture demonstrations ____
    d. Other ____________ ____

84. What is the quality of the teaching aids that are available?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

85. Is there a sufficient amount of laboratory space?
    a. Yes ____
    b. An inadequate amount ____
    c. There is not any laboratory space ____

86. Is there necessary equipment available in the laboratories?
    a. Yes ____
    b. An inadequate amount ____
    c. There is almost no equipment ____

87. What is the status of the laboratory equipment (circle the answers which correspond to the status of the equipment?
    a. The equipment is obsolete ____
    b. The equipment is up-to-date ____
    c. It is poorly maintained ____
    d. It is well maintained ____

88. Are the professors provided with private or share offices?
    a. Private offices ____
    b. Shared offices ____
    c. Other ____________ ____
    d. Office space is not provided ____

89. Is there a system which is followed for the professors/researchers to obtain funds to purchase equipment and supplies necessary for their work? ☐ YES ☐ NO

90. If yes, how efficient is this system in terms of actually obtaining the funds?
    a. Very efficient ____
    b. Efficient ____
    c. Inefficient ____

91. Do the professors have secretarial or clerical support?
    a. Yes, a good amount ____
    b. Some clerical/secretarial support ____
    c. Inadequate clerical/secretarial support ____
    d. None ____

92. How would you rate the overall maintenance of the institute's facilities?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

93. How would you describe the atmosphere of the department you are in?
    a. Very good ____
    b. Good ____
    c. Fair ____
    d. Poor ____

94. How would you rate the communications between the administration and the department or professors?
    a. Poor ____
    b. Fair ____
    c. Good ____
    d. Excellent ____

95. In general, why do professors choose this profession?
    a. Pay ____
    b. Enjoy teaching ____
    c. Want to do research ____
    d. Like the college/university atmosphere ____
    e. For the prestige/position ____
    f. Could not find other work once received a PhD ____
    g. Other ______________________ ____

96. What do you enjoy most about your profession today?
   a. Pay scale ___
   b. Teaching ___
   c. Research ___
   d. University atmosphere ___
   e. The prestige/position in society ___
   f. Other ___

97. What are the disadvantage of your chosen profession?
   a. Pay scale too low ___
   b. Teaching load is too heavy ___
   c. Research is difficult with the circumstances ___
   d. The university atmosphere is tense ___
   e. Administration problems ___
   f. Department atmosphere ___
   g. The work load is too heavy ___
   h. Other ______________ ___

98. Why did you choose this particular higher learning institute?
   a. It is in my home country/city ___
   b. It has a reputable department in my field ___
   c. It is the only one in the region where I can teach in my field ___
   d. Other ______________ ___

99. Are there enough professors for the teaching/research demands? YES NO

100. If there are not enough professors, why?
   a. There are not enough funds to hire more ___
   b. The pay is too low ___
   c. There are no suitable candidates ___
   d. The work is too stressful ___
   e. Other ______________ ___

101. In your opinion what changes should be done to assist the professors and teachers in teaching the students?
   a. More time to prepare classes and keep up with the literature in the field ___
   b. Higher salaries to attract and keep good employees ___
   c. Time off to work in industry or go on sabbaticals ___
   d. More secretarial and clerical assistance ___
   e. Better research facilities ___
   f. Smaller classes ___
   g. Lighter teaching load ___
   h. Other ______________ ___

102. If three things were to be improved upon at the institute what should they be?

a. Improvement of curriculum ____
b. More printed materials/books ____
c. Improvement of the laboratory equipment ____
d. Better classroom facilities ____
e. Better laboratory facilities ____
f. Higher education standards ____
g. Improvement of the administration ____
h. Improvement of the library collection ____
i. Other ______________________ ____

QUESTIONNAIRE FOR GRADUATES

1. Age: ______________

2. Sex: ______________

3. Specialty of training

   (a) Civil engineering ____
   (b) Mechanical ____
   (c) Electrical ____
   (d) Chemical ____
   (e) Other (specify) ____

4. Where did you get your engineering training

   (a) At home:
   Years ____
   Degree ____
   (b) Abroad:
   Years ____
   Degree ____

5. Special courses taken in the last three years
   ____

6. Present occupation
   (a) In engineering ____
   (b) Related to degree (engineering) ____
   (c) Not related to engineering ____

7. Employer
   (a) Industry and Services ____
   (b) Government ____
   (c) Education ____

8. Function within the Co..
   (a) Administrator ____
   (b) Professional and technical ____
   (c) Sales ____
   (d) Other ____

9. Is this your first job? ☐ YES ☐ NO

10. If no, where did you work before, and in what capacity?

11. How long did it take you to find a job after graduation?
    (a) 3 months or less
    (b) 6 months
    (c) 9 months
    (d) 1 year or more

12. How did you get your first job?
    (a) Through school placement
    (b) Through personal contacts
    (c) Through newspaper ads

13. How much do you earn now

14. How much did you earn last year

15. How much did you earn the year before last

16. When you graduated, did you expect to earn
    (a) More than now
    (b) Less than now
    (c) About the same
    (d) Don't know

17. Is your present job related to your training? YES NO

18. If no, why?
    (a) I did not find work in the specialty
    (b) I chose to work in something else

19. What type of knowledge do you think is primarily needed for performing efficiently in your job?
    (a) Theoretical
    (b) Practical
    (c) Experience
    (d) Theoretical and practical
    (e) Theoretical and experience
    (f) Practical and experience

20. Are you applying in your work what you learned in engineering school?
    (a) No
    (b) A little
    (c) A lot

21. If the answer is (b) or (c), what part of your education-training was helpful?

		No help	A little help	A lot of help
(a)	Courses in mathematics	____	____	____
(b)	Courses in statistics	____	____	____
(c)	Courses in sciences	____	____	____
(d)	Specific engineering courses	____	____	____
(e)	Computer experience	____	____	____
(f)	An internship, field experience	____	____	____

22. Are you satisfied with the training given to you in engineering school?

(a) Very satisfied ____
(b) Satisfied ____
(c) Little satisfied ____
(d) Dissatisfied ____

23. If answer is (c) or (d), why?

(a) The curriculum did not include important areas ____
(b) The curriculum was out of date ____
(c) Subjects were not well taught. ____
(d) Books and materials were not available ____
(e) Too few laboratory exercises and practical demonstrations ____
(f) Obsolete equipment and materials in short supply ____
(g) Too much theory and little practice ____
(h) Examinations stress recall knowledge rather than reasoning power.

24. If the answer is (a) or (b), what aspects were most satisfying

(a) Curriculum ____
(b) Materials ____
(c) Teaching methods ____
(d) Laboratories and equipment ____
(e) Practical work ____

25. How satisfied are you with what you are doing in your job?

(a) Very satisfied ____
(b) Satisfied ____
(c) Not satisfied ____

26. If (c), does it pertain to any of the following
    - (a) Not using the training received in school ____
    - (b) Not what I expected to be doing with the training I received ____
    - (c) Was not prepared enough in school for position ____
    - (d) The work is too basic compared with training received in school ____
    - (e) I do not like the work atmosphere ____
    - (f) Other ____

27. Of (a) or (b) of #26, is it because
    - (a) I am doing what I expected to be doing with the training I received in school ____
    - (b) I am applying my knowledge and skills ____
    - (c) I am sufficiently challenged and I am learning more ____
    - (d) I like the work atmosphere ____
    - (e) Other (explain) ____

Appendix I

B COEFFICIENTS FOR ENGINEERS IN DIFFERENT INDUSTRIES

Mining and Quarrying	.574
Manufacturing	.762
Petroleum and Coal	.411
Metal and Metal Products	.649
Primary Metals	.492
Iron and Steel	.505
Non-ferrous	.589
Fabricated Metal Products	.387
Machinery	.810
Electrical Machinery and Equipment	.799
Transportation and Warehousing	.723
Utilities	.472

Source: Manuel Zymelman Occupational Structures of Industries, Washington, D.C., World Bank, 1980

Appendix II

LIST OF INDUSTRIES

1. Agriculture, Forestry and Fishing
2. Agriculture
3. forestry and logging
4. Fishing
5. Mining and Querring
6. Coal
7. Metal
8. Petroleum and Natural Gas
9. Querring and Other
10. Construction
11. Manufacturing
12. Food and Beverages
13. Tobacco and Tobacco Products
14. Textile Mill Products
15. Clothing and Other Fabr. Textiles
16. Footwear
17. Leather and its Prod. (exc Ftwr)
18. Leather and its Prod. (inc Ftwr)
19. Furniture and Fixtures
20. Lumb and Wood Prod (exc Furn)
21. Lumb and Wood Prod (inc Furn)
22. Paper and Paper Products
23. Printing and Publishing
24. Rubber Products
25. Chemicals and Chemical Products
26. Petroleum and coal Products
27. Stone and Clay Products
28. Glass, Stone and Clay Prods.
29. Metal and Metal Products
30. Primary metals
31. Iron and Steel
32. Nonferrous
33. Fabr Metal Prod. (exc Mach)
34. Machinery (exc Electrical)
35. Electrical Mach and Equip
36. Transportation Equipment
37. Motor Vehicles, etc.
38. Profess. and Scientific Instruments
39. Miscel Mfg (inc Instruments)
40. Transportation and Warehousing
41. Railroad
42. Trucking
43. Water
44. Air
45. Warehousing
46. Other
47. Communications
48. Utilities
49. Trade
50. Wholesale Trade
51. Retail Trade
52. Finance, Insurance and Real Estate
53. Services
54. Government
55. Education
56. Medical
57. Business
58. Personal, Recreation, Misc.

Average (A) and High (H) Values of Occupational Composition of Industries
(Per Thousand)

INDUSTRY	*1*		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*		*10*		*11*		*12*		*13*		*14*		*15*	
OCCUPATION	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*
Prof. & Tech. Wkrs.	5	16	4	14	20	46	27	109	58	120	42	99	84	162	170	250	46	95	38	69	48	86	28	47	40	62	22	34	9	19
Eng. & Tech.	1	3	1	3	6	14	6	13	33	79	21	33	49	85	81	123	25	63	31	52	25	57	9	20	12	20	10	24	3	9
Engineers	1	1	1	1	3	6	3	5	18	41	11	23	24	43	50	60	12	30	14	29	11	27	4	8	5	8	5	10	1	2
Civil & Arch.					3	4			2	5	1	1	3	4	5	6	2	5	10	21	1	1	1	1	1	1				
Electrical									1	3	1	2			6	6	1	3	1	4	3	8								
Mechanical							2	2	3	6	2	2	3	3	10	14	3	7	1	3	4	8	1	3	2	3	1	2		
Industrial									3	4	1	1					2	3			2	6	1	2			3	5	1	1
Chemical									1	2					5	6	1	1			1	2	1	1			1	1		
Metallurgy									1	1			2	2																
Ind. Specific									9	15	5	6	14	16	29	30	5	8												
Other									8	16	6	10	11	25	25	54	4	8	6	17	4	10	2	4	2	2	3	8		
Technicians	1	2	1	2	4	9	4	9	13	54	10	18	23	58	34	78	10	36	14	34	12	35	4	10	7	14	5	16	3	6

INDUSTRY	*16*		*17*		*18*		*19*		*20*		*21*		*22*		*23*		*24*		*25*		*26*		*27*		*28*		*29*		*30*	
OCCUPATION	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*
Prof. & Tech. Wkrs.	12	17	14	25	10	19	9	24	11	23	12	28	40	77	101	152	40	70	122	181	126	186	38	60	36	68	36	73	51	91
Eng. & Tech.	3	8	4	88	3	9	4	9	5	13	7	15	20	36	9	19	20	45	40	84	70	121	17	33	18	37	23	58	33	47
Engineers	2	3	2	5	2	3	1	3	2	4	3	6	8	21	2	4	10	24	21	45	39	56	8	15	8	19	10	35	18	29
Civil & Arch.									1	1	1	1	2	2					1	2	3	5	3	4	2	5	1	2	1	3
Electrical													1	2	1	1	1	1	1	3	3	5	1	1	1	1	1	2	2	4
Mechanical			1	1					1	1	1	1	2	7	1	2	3	5	3	7	9	14	1	2	1	3	3	7	5	8
Industrial			1	1							2	2	3	5	1	1	5	7	3	7	4	7	2	3	3	6	1	2	4	7
Chemical													1	2			3	7	14	23	17	26			1	2			1	2
Metallurgy																											2	4	3	6
Ind. Specific																					4	5								
Other			1	1							2	2	4	12	2	3	5	9	6	27	11	29	4	7	4	10	5	12	5	12
Technicians	2	4	3	8	2	9	3	6	3	8	4	9	10	22	6	11	9	24	17	45	31	72	10	20	9	19	11	25	14	26

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Average (A) and High (H) Values of Occupational Composition of Industries (Continued)
(Per Thousand)

INDUSTRY	*31*		*32*		*33*		*34*		*35*		*36*		*37*		*38*		*39*		*40*		*41*		*42*		*43*		*44*		*45*	
OCCUPATION	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*
Prof. & Tech. Wkrs.	43	71	53	89	31	65	75	120	101	197	60	138	66	96	112	214	30	65	44	83	37	56	6	11	140	290	154	228	15	25
Eng. & Tech.	28	36	30	47	21	59	57	111	73	158	45	113	49	80	41	79	13	32	10	23	22	49	2	3	10	21	35	83	6	10
Engineers	17	21	20	27	9	38	26	59	33	84	20	57	21	41	25	48	5	11	4	12	8	13	1	2	5	10	14	26	3	5
Civil & Arch.	1	2	3	3	1	2	1	2	1	1	1	2							1	3	3	5			2	4	1	2		
Electrical	2	2			1	1	3	6	20	36	2	7	3	3	9	14			1	1	2	2					2	4		
Mechanical	5	8	5	6	4	11	15	31	6	17	11	20	13	16	7	15	1	2	1	3	1	1			2	5	5	9	3	3
Industrial	3	4	5	7	2	5	5	11	4	14	5	11	4	4	11	11	2	6							1	1	2	2		
Chemical									1	1																				
Metallurgy	3	4	6	7			1	1																						
Ind. Specific																														
Other	2	3	3	3	5	9	12	25	14	32	6	16	9	17	10	17	2	5	3	7	3	6			1	4	6	12		
Technicians	11	17	15	20	11	24	26	71	37	89	20	58	31	50	22	38	7	17	6	19	14	39	1	2	6	10	23	65	3	5

INDUSTRY	*46*		*47*		*48*		*49*		*50*		*51*		*52*		*53*		*54*		*55*		*56*		*57*		*58*	
OCCUPATION	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*	*A*	*H*
Prof. & Tech. Wkrs.	21	64	61	140	98	155	22	43	29	51	19	43	73	229	295	430	120	190	758	867	627	743	328	413	108	183
Eng. & Tech.	8	23	41	91	71	109	5	13	8	18	2	7	12	63	22	47	34	67	6	13	2	6	124	266	9	25
Engineers	3	9	15	44	36	61	2	5	5	12	1	2	5	17	9	22	14	43	3	7	1	2	57	135	4	13
Civil & Arch.			2	3	7	15			1	1			3	9	5	14	7	18	1	1			38	105	1	1
Electrical	1	1	11	23	21	36			1	1					1	2	1	2	2	2			4	9	1	2
Mechanical	1	2	1	1	4	9			1	1			2	2	1	2	2	2	2	2			6	11	1	2
Industrial			3	3	2	3							1	1	1	1	2	3					5	6		
Chemical					1	1																	1	1		
Metallurgy																										
Ind. Specific																	1	1								
Other	1	2	4	13	13	41	1	3	3	8			1	3	4	18	4	7	1	3	1	1	13	36	1	2
Technicians	4	18	25	82	34	73	3	7	4	7	2	5	6	38	12	23	19	40	3	8	2	4	62	113	5	15

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Appendix III

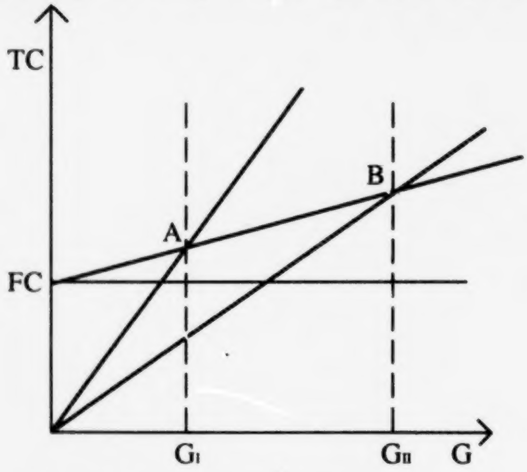
LOCAL vs FOREIGN TRAINING

The size of the local market for engineers is a major determinant of the decision to establish a local engineering training program.

It is possible to fill the need for a given type of engineer by:

(a) Importing foreign engineers
(b) Training engineers at home
(c) Training nationals abroad.

Each of these possibilities entails specific costs and benefits. From a strict economic viewpoint the break even point for a given size department is given by:



G = Number of graduates at full capacity

$$G_I = \frac{FC}{\sum_n - \frac{S_I - S_L}{(1 + r)^n} - AVC}$$

$$G_{II} = \frac{FC}{\frac{C_a}{P} - AVC}$$

where:

G_I = Breakeven point for imported engineers
G_{II} = Breakeven point for training abroad
FC = Annualized fixed costs x years required to graduate
S_I = Salary of imported engineers
S_L = Salary of local engineers
AVC = Average annual variable costs of training (local) x years required to graduate
C_a = Cost of training a local engineer abroad
P = Probability of returning home
r = Rate of discount
n = Working life.

There are, however, other considerations that have to be taken into account in a choice between training at home, abroad, or importing engineers. Assuming that the quality of engineer is the same in the three cases, there are positive externalities attached to having a local training institution. As a center for higher learning the engineering program can contribute to society through research, advice, provision of professional links with similar institutions abroad, and providing opportunities for upgrading the professional knowledge of engineers. The existence of an engineering faculty may also provide economies of scale to other faculties especially in the sciences. All these non-pecuniary benefits are difficult to estimate quantitatively, but it is possible to infer the minimum value that these benefits must assume in order to justify one choice or another.

If

$$C_n = C_t - B = C_a$$

C_t = Cost of local training

Where

C_n = Net cost of local training
C_t = Cost of local training
B = Non pecuniary benefit
C_a = Cost of training abroad or importing engineers

Then

$$B = C_t - C_a$$

If the assessment is that benefits of externalities are worth more than $C_t - C_a$ then local training becomes more profitable. While these externalities lower the cost/graduate of local institutions, there are other factors that tend to affect the costs of training abroad or hiring foreign engineers such as availability of foreign exchange, and/or over and under evaluation of foreign exchange.

Appendix IV

QUESTIONNAIRE FOR ENGINEERS

1. Age ___

2. Sex ___

3. Status:
   (a) Expatriate ___
   (b) National ___

4. Specialty:
   (a) Civil ___
   (b) Mechanical ___
   (c) Electrical ___
   (d) Industrial ___
   (e) Chemical ___
   (f) Metallurgical ___
   (g) Industry specific (i.e., petroleum engineers) ___
   (h) Other (specify) ___

5. Post Secondary/Education

Name of School	Years	Degree	Home	Abroad
___	___	___	___	___
___	___	___	___	___
___	___	___	___	___
___	___	___	___	___

6. Employed: ☐ YES ☐ NO

7. If yes, place of work name: ___

8. Type of employer:
   (a) Self employed ___
   (b) Private ___
   (c) Public Service ___
   (d) Parastatal ___
   (e) Education ___
   (f) Military ___
   (g) Other ___

9. Industrial Classification of Employer (provide local list of industrial classification) ______

____

10. Number of employees ___

Appendix V

ENROLLMENT AND OUTPUT

Name of Program: ____________

Instructions: Complete for each of the past 5 years. This form is suitable for programs lasting one to five years.

Program or Specialization	*Length of Program*	*Year*	*1st Year*	*2nd Year*	*3rd Year*	*4th Year*	*5th Year*	*Output (Graduates)*	*New Entrants*
		1986							
		1987							
		1988							
		1989							
		1990							
		Repeaters							
		1986							
		1987							
		1988							
		1989							
		1990							
		Dropouts							
		1986							
		1987							
		1988							
		1989							
		1990							

Appendix VI

COST DATA

When evaluating an engineering training institution, special attention should be paid to patterns and levels of expenditures. Raw data on unit costs (costs per student or cost per graduate) are not sufficient to indicate effectiveness or efficiency. For example, lower unit costs could be the result of a failure to replace equipment or a drop in the use of consumable materials, or the cramming of a large number of students in classes and laboratories. It is also important to look at the evaluation of costs and its components over time to discern trends in the allocation of resources. In general, an analysis over the last five years will provide answers as to the change in the levels and structures of costs. A form for the analysis of cost is given in Appendix 7.

Analysis of Costs

The cost of a particular program in engineering, say electrical engineering, is composed of two parts: (a) costs specific to the program; and (b) joint costs with other programs. There is no conceptual problem with specific costs, once identified. However, the allocation of joint costs requires criteria.

For Administration Costs

$$ADM_j = TCA \times \frac{S_j}{\sum_j S_j}$$

where

ADM_j = Cost of administration of program j
TCA = Total cost of administration
S_j = Students in program j

Teaching Costs of Joint Courses (for example, engineering students taking a general physics course)

$$CI_{jk} = TCI_k \times \frac{HRS_{jk}}{\sum_j HRS_{jk}}$$

$$HRS_{jk} = S_{jk} \times H_{kj}$$

Where

CI_{jk} = Cost of instruction of course k for program j
TCI_k = Total cost of instruction of course k
HRS_{jk} = Hours instruction of course k required by program j
S_{jk} = Students of program j taking course k
H_{kj} = Hours spent by students of program j in course k

Appendix VI

Cost of Laboratories and Classrooms

$$TCLCl_j = TClC_k \times \frac{H_{kj} \times S_j}{\sum_j H_{kj} S_j} + TLC \times \frac{HRSC_j}{\sum_j HRSC_j}$$

TCLCl = Total cost of laboratory and classrooms
TLC = Total laboratory cost
TClC = Total classroom cost

Where TLC and TC1C are annualized values[1] of the investment in laboratories and classroom respectively.

---

[1] $$a(r,n) = \frac{r(1+r)^n}{(1+r)^n - 1}$$

where
a = Annualization factor.
n = Expected service life of the building and equipment.
r = Rate of discount.

Appendix VII

ANNUAL OPERATING COSTS

Name of Program: ____________________

Salaries and Allowances

	1988	1989	1990
Professors and instructors			
Salaries	___	___	___
Other allowances	___	___	___
Non-academic professional and Technical Staff			
Clerical staff	___	___	___
Service and other staff	___	___	___

Maintenance Building, Equipment

Consumable materials	___	___	___
Utilities	___	___	___
Student maintenance	___	___	___
Travel	___	___	___
Other [1]	___	___	___

Capital Expenditure

Instructions: Complete for each of the past three years.

Name of Program: ____________________

Construction	___	___	___
New equipment and machinery	___	___	___
Other	___	___	___
Total	___	___	___

---

[1] Only if Central Administration is specific to Engineering.

Appendix VII

Annual Operating Costs of Central Administration [2]

	1988	1989	1990
Salaries and Allowances			
Professionals and Administrators	___	___	___
Technical Staff	___	___	___
Clerical staff	___	___	___
Service and other staff	___	___	___
Maintenance Building, Equipment			
Utilities	___	___	___
Materials	___	___	___
Travel	___	___	___
Other[3]			

---

[2] Only if Central Administration is specific to Engineering.

[3] If more than 10 percent, itemize.

Appendix VIII

COST AND OUTCOMES

There are two types of measures: cost per student, and cost per graduate. Cost per student raises no problems, being merely total cost over any time period divided by the number of students undergoing training in that period

$$C_s = \frac{TS}{s}$$

where

C_s = cost per student
TC = total cost
S = number of students

The calculation of cost per graduate is more complicated because estimates of the rate of dropout, repetition, and examination failure are needed.

Cost per graduate can be calculated as follows:

$$C_g = \frac{u\sum_{t}^{t-1} C + \sum_{t}^{t-2} C + \ldots n\sum_{t}^{t-m} C + s\sum_{t}^{t-1} C + w\sum_{t}^{t-2} C + x\sum_{t}^{t-m} C}{g}$$

where
C_g = cost per graduate in year t
C = average cost per student
g = number of graduates in year t
u, w, n = group of graduates in year t classified according to number of years spent in training
s, w, x = are group of dropouts and examination failures classified according to number of years spent in training

This measure of cost per graduate implies a zero valuation of dropouts and examination failures.

When detailed data are difficult to obtain a fairly good approximation is:

C_g = C x a

Appendix VIII

where
a = Estimated number of years to produce a graduate.

(1) Year	(2) Year of Study	(3) Enrollments	(4) Difference	(5) Cumulative Years	(6) (4)x(5)
x-3	1	n_1	$(n_1 - n_2)$	1	1 x $(n_1 - n_2)$
x-2	2	n_2	$(n_2 - n_3)$	2	2 x $(n_2 - N_2)$
x-1	3	n_3	$(n_3 - n_4)$	3	3 x $(n_3 - n_3)$
x	grad 4	n_4	$(n_4$ - grad)	4	4 x $(n_4$-grad)
					total

a = Grads/Total

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